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NOTES ON THE KUNENE RIVER, SOUTHERN ANGOLA

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THE Kunene is one of the two solitary perennial rivers draining into the South Atlantic from the South African continent between Benguela (lat. 12° 34′ S.) and Cape Town (lat. 34° S.); that is, over a distance of approximately 1600 miles along the coast. The other is the Orange River 1200 miles further south, and this latter great river, which drains an area of about 336,000 square miles, is frequently reduced to a very small discharge during the spring months, and has on numerous occasions during the past century ceased to flow altogether in its lower reaches. The Kunene and Orange rivers are the northern and southern boundaries respectively of the South-West Africa Protectorate, formerly German South-West Africa. All along its 1200 miles of coast-line a great number of rivers are shown on the maps; all of them are, however, dry watercourses, discharging only at rare intervals.

The Kunene has, in recent years, attracted a considerable amount of attention due to various causes. In the first place, it has become politically important in connection with the settlement of the boundary dispute which has existed between Portugal and Germany for the past thirty-four years. Secondly, Prof. Schwarz's propaganda in favour of his theories and scheme for recreating the Kalahari lakes and swamps and thereby changing the climate of South Africa, has made many people familiar with the Kunene by name.

The Kunene is an important factor in Prof. Schwarz's projects, and it is unfortunate that he did not possess first-hand or even accurate information about it before formulating his scheme, as many of his vital data concerning this river are erroneous. Prof. Schwarz is not the only one who has gone astray owing to wrong information about this river.

During July and August of 1920 I was in charge of the British Commission which met a Portuguese Commission at the great falls of Rua Cana on the Kunene to negotiate a settlement of the old standing frontier dispute and to delimit the boundary. The British commissioners were, so far as is known, the first Britishers to explore properly the Kunene between Erickson's Drift and the great falls—the most interesting and

important section of the river. It was from the outset apparent that nearly all the information concerning this section of the river, both official and otherwise, was erroneous and wholly misleading. The Portuguese have known this river intimately for a very long time, and the paucity of reliable information regarding so important a geographical feature is surprising.

The time appears now opportune to place on record a few facts relating to the Kunene, and more especially to the short length of about 30 miles in which it makes its first great plunge from the high Southern African tableland down the great coastal escarpment to the Atlantic Ocean.

Before dealing with the particular length of the river in question it is desirable to give some general information about the Kunene and its great sister river the Okavango, as in dealing with any of the diverse problems which may arise concerning the reclamation of the great plains of Ovamboland or the Kalahari, both these rivers must be dealt with.

The drainage areas of the Kunene and the Okavango rivers lie side by side, and the watershed separating them has no very pronounced topographical features. The headwaters of both rivers lie between the 12th and 13th degrees of south latitude, on the crest of the Angola highlands. The watershed between the Kunene and Okavango, flowing south, and the river systems draining north-west to the Atlantic or northwards to the Congo likewise presents no striking features. This watershed is followed very closely by the railway from Lobito Bay to the Katanga area.

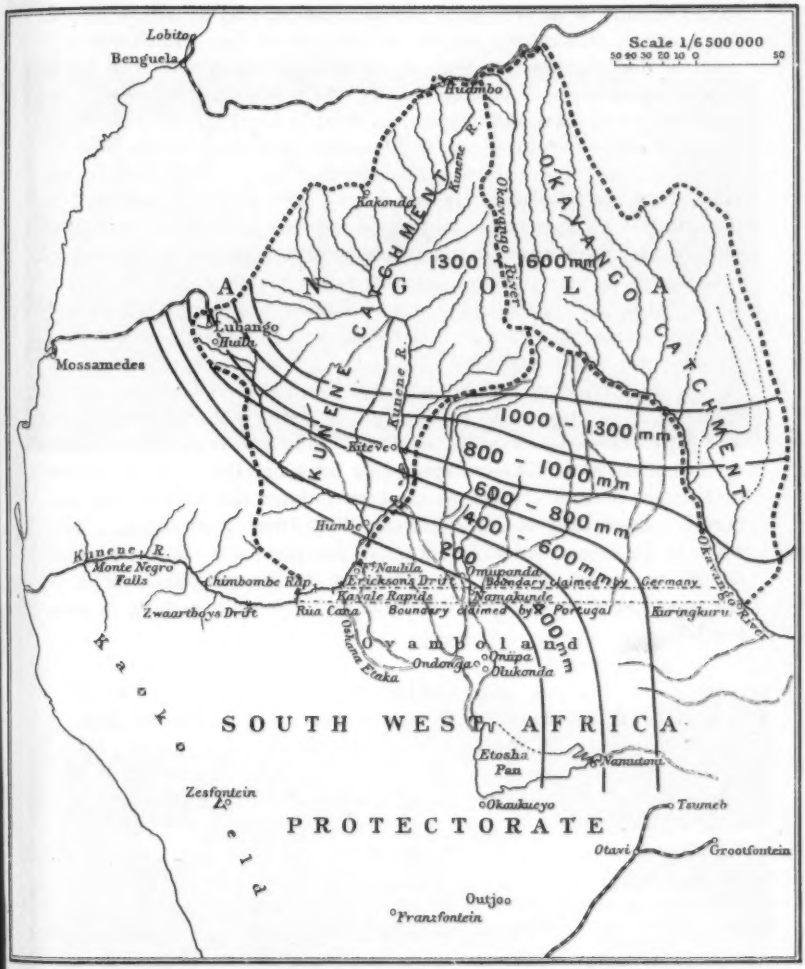
The information given in these notes regarding the catchment areas of the two rivers is based upon the 1917 edition of the 1/2,000,000 Portuguese map of Angola published by the Comissão de Cartografia. This edition is supposed to be entirely new, and in the levels shown there are many differences from the previous edition of 1912. An article in vol. 31 of the *Mitteilungen aus den Deutschen Schutzgebieten* entitled "Studien über Angola" has also been made use of.

The general structure of southern Angola is but little different from that obtaining further south. Along the Atlantic coast there is a belt of arid country varying from 50 to 100 miles. Then comes the great coastal barrier or escarpment, on the top of which is the vast plateau extending east for hundreds of miles with but little variation in level from west to east, but with a very gradual fall to the south from the central watershed.

From levels shown on the map it is possible to plot approximately longitudinal sections of the two rivers. The recorded levels are, however, not bed levels, but refer to spots on or near the banks, such as police or military posts. These are, in many cases, at an appreciable height above the river-bed. Allowing for this, the gradient of the Kunene bed from Kiteve to Erickson's Drift, *i.e.* over a distance of 100 miles, is somewhere between 1/3000 and 1/4000. It is clear, however, that, speaking generally,

the Okavango River has a much flatter gradient than the Kunene and is a much more sluggish river.

Considering the great length of time Angola has been settled, the



Rainfall of Kunene and Okavango Basins

paucity of meteorological data and the short period over which these extend is surprising. The accompanying table of mean annual rainfall in southern Angola and in the territory immediately to the south of it has

been prepared by the Meteorological Department of the Union of S.A. Table No. II. shows the seasonal distribution of rainfall in the Huila district of southern Angola, which is typical of the whole area within the catchments. The only useful information on the subject of rainfall in this country is derived from German sources, and an article on the Meteorology of southern Angola in vol. 30 of the *Mitteilungen a.d. Deutschen Schutzgebieten* has been drawn upon. It will be seen from Table No. II. that there is a pronounced dry season varying from four to six months, between May and October, followed by a wet period. The latter has generally two peaks, one in December and the other in March. During January and February the rainfall is less. The figures in the table, which are calculated only over a very short period of time, do not indicate this as clearly as is said to be the case by reliable Portuguese officers who have been in the country for a long time. From close observation on the Kunene by these officers, it appears that there is a minor flood period in November and December, following the six months' drought, then a lull in January and February; and finally the main flood period during March and April.

For the purpose of calculating the run-off, I have divided the catchments of the two rivers into zones according to the mean rainfall in each. The particulars are given in Table III. It will be seen that the Kunene catchment above the Kavale Rapids, near Erickson's Drift, is about 30 per cent. larger than the Okavango catchment above Kuringkuru, near the border between Angola and the South West-Africa Protectorate. The whole of the Okavango catchment above this point is in regions of good rainfall, whereas about 4000 square miles of the Kunene catchment is in arid or semi-arid country from which the run-off is either nothing or very small.

TABLE I.

RAINFALL IN SOUTHERN ANGOLA AND NORTHERN S.W.A. PROTECTORATE.

Station.	Lat. S.	Long. E.	Average rainfall in millimetres.
Loanda	8° 49′ ...	13° 13′ ...	270
Malange	9° 33′ ...	16° 38′ ...	1240
Kakonda	13° 44′ ...	15° 2′ ...	1534
Villa Bandeira	14° 49′ ...	13° 30′ ...	978
Oniipa	17° 54′ ...	15° 53′ ...	420
Ondonga	17° 58′ ...	15° 50′ ...	412
Olukonda	18° 00′ ...	16° 00′ ...	538
Namutoni	18° 48′ ...	16° 52′ ...	384
Okakweyo	19° 10′ ...	15° 54′ ...	397
Zesfontein	19° 16′ ...	13° 37′ ...	37
Grootfontein	19° 32′ ...	18° 4′ ...	567
Otavi	19° 40′ ...	17° 20′ ...	541
Outjo	20° 6′ ...	16° 6′ ...	423
Franzfontein	20° 12′ ...	15° 00′ ...	225

KUNENE RIVER NEAR ERICKSON'S DRIFT

THE UPPER KAVALE RAPIDS

GORGE BELOW THE UPPER KAVALE RAPIDS

THE WESTERN FALL, RUA CANA

TABLE II.

MEAN MONTHLY RAINFALL IN MM. IN SOUTHERN ANGOLA.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Sa. da Bandeira *...	95	105	163	157	13	—	—	—	12	46	138	151	880
Huila	101	161	200	67	4	—	—	—	7	33	136	193	902
Omupanda... ...	121	160	80	56	6	1	—	—	11	5	43	141	624
Kakonda† ...	245	408	280	194	25	—	—	—	45	118	192	241	1784

TABLE III.

KUNENE RIVER ABOVE ERICKSON'S DRIFT.

Catchment areas, rainfall and estimated run-off.

Zone.	Rainfall.		Area in sq. miles.	Total rainfall in cub. feet per annum (approx.).	Run-off percentage assumed.	Total run-off in cub. feet per annum (approx.)
	mm.	ins.				
1	1500	59·02	21,830	2993×10^9	10	$299{\cdot}0 \times 10^9$
2	1150	45·28	2,227	234×10^9	9	$21{\cdot}0 \times 10^9$
3	900	35·43	2,079	171×10^9	8	$13{\cdot}5 \times 10^9$
4	700	27·56	1,733	111×10^9	7	$8{\cdot}0 \times 10^9$
5	500	19·68	2,970	136×10^9	5	$7{\cdot}0 \times 10^9$
6	300	11·81	2,722	75×10^9	2	$1{\cdot}5 \times 10^8$
7	100	3·94	1,336	12×10^9	1	—
			34,897	3732×10^9		$350{\cdot}0 \times 10^9$

TABLE IV.

OKAVANGO RIVER ABOVE KURINGKURU.

Catchment areas, rainfall and estimated run-off.

Zone.	Rainfall.		Area in sq. miles.	Total rainfall in cub. feet per annum (approx.).	Run-off percentage assumed.	Total run-off in cub. feet per annum (approx.).
	mm.	ins.				
1	1500	59·02	21,206	2908×10^9	10	291×10^9
2	1150	45·28	2,208	232×10^9	8	19×10^9
3	900	35·43	2,475	204×10^9	6	12×10^8
4	700	27·56	841	54×10^9	5	3×10^9
			26,730	3398×10^2		325×10^9

* Lubango. † This monthly record is for one year only.

TABLE V.

ESTIMATED MEAN MONTHLY DISCHARGE OF THE KUNENE AT THE KAVALE RAPIDS.

Month.	Mean discharge in cusecs.	Total approx. volume of discharge in cubic feet.
October	2,000	5×10^9
November	5,000	13×10^9
December	10,000	26×10^9
January	10,000	26×10^9
February	20,000	52×10^9
March	40,000	103×10^9
April	30,000	77×10^9
May	10,000	26×10^9
June	5,000	13×10^9
July	2,000	5×10^9
August	1,000	3×10^9
September	500	1×10^9
Total		350×10^9

The total amount of rainfall running off these two catchments, measured as stream flow at Erickson's Drift on the Kunene and at Kuringkuru on the Okavango, respectively, is estimated by me to be 350,000 million cubic feet per annum in the Kunene and 325,000 million cubic feet per annum in the Okavango. For each zone I have adopted a different run-off coefficient. These coefficients have been fixed in the light of experience gained in the Union of South Africa from about fifteen years of elaborate study of stream flow in its relation to rainfall, and in my opinion these coefficients are optimistic, especially in the case of the Okavango; though Mr. Karlson, late Hydrographic Surveyor in the Union Irrigation Department, has in a recent publication assumed as much as 20 per cent. run-off in the wettest zone of the Kunene catchment. Now while there is no very large difference in the estimated total annual run-off from the two rivers, the mode of run-off differs enormously. The seasonal variation of the Kunene flow reminds one more of the big South African rivers of the Union, having a very small discharge in the winter and spring months, and a very heavy flood discharge during the rainy season. The Okavango, on the other hand, appears to have a much smaller range, and owing to the shape and flat nature of its catchment and to its generally higher rainfall, a much higher mean discharge is maintained throughout the dry period.

The minimum flow of the Kunene has been studied with some care in recent years by the Portuguese; and during my stay on the river in July 1920 I personally watched the variations of the discharge very closely.

The possibilities of utilizing the power of the great Rua Cana falls has stimulated the Portuguese military engineers to make periodical observations of the dry-weather flow. Between 24 June and 7 July, while I was camped at various points on the banks of the Kunene, the very rapid shrinkage in the discharge was most pronounced and the daily

fall in the water-level was appreciable. On 4 July I computed the discharge to be approximately 1000 cubic feet per second, at a point a short distance above the crest of the great falls. The two Portuguese military engineers on the Boundary Commission, who had considerable knowledge of the river, informed me that at its lowest the discharge would be approximately half this amount, viz. 500 cubic feet per second. From information thus gathered, and having regard to the seasonal distribution of the rainfall, I have attempted to make an estimate of the mean monthly discharge of the Kunene below the Kavale Rapids. This is given in Table V.

From its source, for about 450 miles, the Kunene flows generally due south. It then takes a south-westerly course for the next 100 miles to Erickson's Drift, after which it turns west and continues more or less in this direction to its mouth. Above Erickson's Drift it pursues a somewhat sluggish course down the great alluvial plain of southern Angola, which, in character, is practically the same as the plain of Ovamboland in the South-West Africa Protectorate. On arriving at Erickson's Drift the river has reached the western margin of the great plateau, and about 5 miles further west commences its descent down the 3000-foot escarpment to the coast.

The altitude above sea-level at the crest of the Kavale Rapids is 3215, and the distance thence to the sea is approximately 200 miles. Erickson's Drift is the spot where the famous trader of that name is said to have taken his waggons across the Kunene into Angola. He must have been a very bold man, as it looks a most unattractive spot for such a purpose, and has not since been used. The drift is near the lower extremity of the great bend, where the Kunene changes its course to the west. The gradient is exceedingly flat, the current very small, and the margins are covered with broad belts of high reeds and swamps, which are intersected with deep creeks and pools infested with crocodiles. The great bend of the river is made round a small cluster of kopjes, composed of red sandstones and grits. These kopjes, called by the Ovashimba natives Okarundu, form a striking landmark for miles around. To the east and south of them lies the vast plain of Ovamboland. It is almost dead-flat from east to west, with a very small gradient from north to south. The plain has been formed by the fine silt brought down from the Angola highlands by the Kunene, Okavango, Chobe, and other big rivers. These deposits have in the course of ages gradually filled up the vast depression which stretched across the southern African plateau roughly between 16° and 22° S. lat., and between 15° and 27° E. long. It is possible that at some very remote date all the drainage from the Angola highlands, then much higher, emptied itself into this great depression, but the combined processes of silting and the erosion of the coastal escarpment working eastwards, gradually diverted more and more of the waters of the Kunene catchment to the South Atlantic. In the same way much of the water of

the Okavango, which at one time found its way into the Etosha Pan on the western side of the great depression, has been forced from want of gradient to seek an easier outlet south-eastwards. So far as the Kunene is concerned, it is clear from an examination of that river below Erickson's Drift that the diversion of the water to the west began at a very remote date, and that the full development of the present system occupied an immense period of time. In its present state the Kunene above Erickson's Drift has the same characteristics as other great rivers traversing alluvial plains. In normal cases such rivers gradually build up their beds to higher and higher levels till the gradient becomes too small, and when a particularly large flood overtops the banks it causes the entire river to roll off its old embanked bed and to establish a new course at lower levels in the valley. In course of time such big rivers swing slowly from side to side of their containing valleys and slowly raise the general level of the alluvial deposit. The great rivers of the Punjab and the Mississippi are typical examples of this process. In the case of the Kunene the silting-up process has reached so advanced a stage that the building-up and rolling-off process has long since been impossible. Further building up of the bed would so reduce the gradient and the velocity that the vast volume of water could no longer be transported, and a state of approximate equilibrium has now, more or less, been attained. A sufficient head of water is automatically maintained to create a large enough average velocity of flow during the flood season to keep the main channel free from silt, and enable the enormous mass of water to transport itself. During very high floods such rivers overtop their banks, and in doing so all the heavier particles of silt in suspension are deposited along the margins of the main channel, owing to the immediate reduction in velocity. The margins of these rivers are therefore invariably at a higher level than is the alluvial land some distance away from the main channel. If the bed is free to rise the process goes on indefinitely, and the river runs on the top of an embankment, like the Indus and the Mississippi—both extreme cases. With the Kunene this, for reasons stated, is not possible, with the result that with the bed-levels stationary and the bank-levels rising, overtopping becomes more and more rare. This accounts for the steady diminution in the amount of annual flooding of the Ovamboland plains. It is necessary to insist upon the fact, however, that even were it possible to produce such overtopping on a large scale, the gradient down the plain is now so small that no really large percentage of the flow could be made to pass down southwards to the Etosha Pan. Some enthusiasts, in ignorance of the fundamental laws of hydraulics, think otherwise.

The critical point on the Kunene is the crest of the little rapid about 5 miles below Erickson's Drift. This rock barrier, fortunately a very hard one, regulates the bed-levels for many miles upstream. The great bend of the Kunene between Fort Naulila and Erickson's Drift, a distance

of about 10 miles, formed and still forms one of the main spillways to the south. Numbers of small spill channels from the south bank converge to form one of the largest of the old Oshanas, or shallow flood channels leading southwards towards the Etosha Pan. This particular channel is known as the Oshana Etaka.

A mile below Erickson's Drift the Kunene enters a clearly defined valley. The sides consist of outcrops of red felspathic grits and conglomerates which form very uniform side slopes of about 1 to 1. Outside these outcrops the country consists, for distances up to half a mile, of hard calcareous tufa covered with very dense bush. The surface is generally level, excepting close to the banks, and rises almost imperceptibly to the sandy flats of the plains behind.

In the first 5 miles to the crest of the Kavale Rapids the alluvial floor of the valley is about 10 feet below the surface of the adjoining country. For about half the distance between the drift and the rapids the river is not much broken up into channels, and for a length of about a mile is confined to a single, almost straight, channel from 150 to 200 yards in width. The banks of the main channel are almost vertical and from 8 to 10 feet to low water. The river channels are bordered by belts of high reeds. Between the river and the southern margin of the valley there is an alluvial flat varying in width from 1000 to 2000 feet. This flat is above the ordinary flood-level. It supports patches of scrub and many scattered trees of large size, but the valley presents generally a bare appearance. On the right or Angola bank of the river conditions appear to be similar, but this side was inaccessible to us. About 3 miles below Erickson's Drift the river becomes more broken, and splits up into a number of channels, the network occupying the entire width of the valley. The ground between these channels is lower than it is further upstream, and is more exposed to flooding. A few isolated trees exist, but, in general, all the exposed land is covered with a dense growth of high reeds. Looked at from the margin of the valley, nothing but a vast expanse of reeds is visible.

Near the Kavale Rapids, about 5 miles below the drift, the valley narrows considerably, and the main stream hugs the right bank. Immediately above the rapids there is a large pool bounded on the north by high rocky banks of the valley, and on the south by a large expanse of reeds. The gradient of the river at this point is very small, and where visible presents a peaceful appearance. The Kavale Rapids are formed by a hard barrier of the same red grits and conglomerates as are referred to above, followed at lower levels by the underlying greenish biotite schists. These rapids have assumed considerable political importance, as will be shown later, and have in the past been generally referred to as the "Upper or Small Cataract" in contradistinction to the "Large Cataract," or Rua-Cana Falls, 25 miles downstream.

The Kavale Rapids are in two sections. There is first of all a rapid

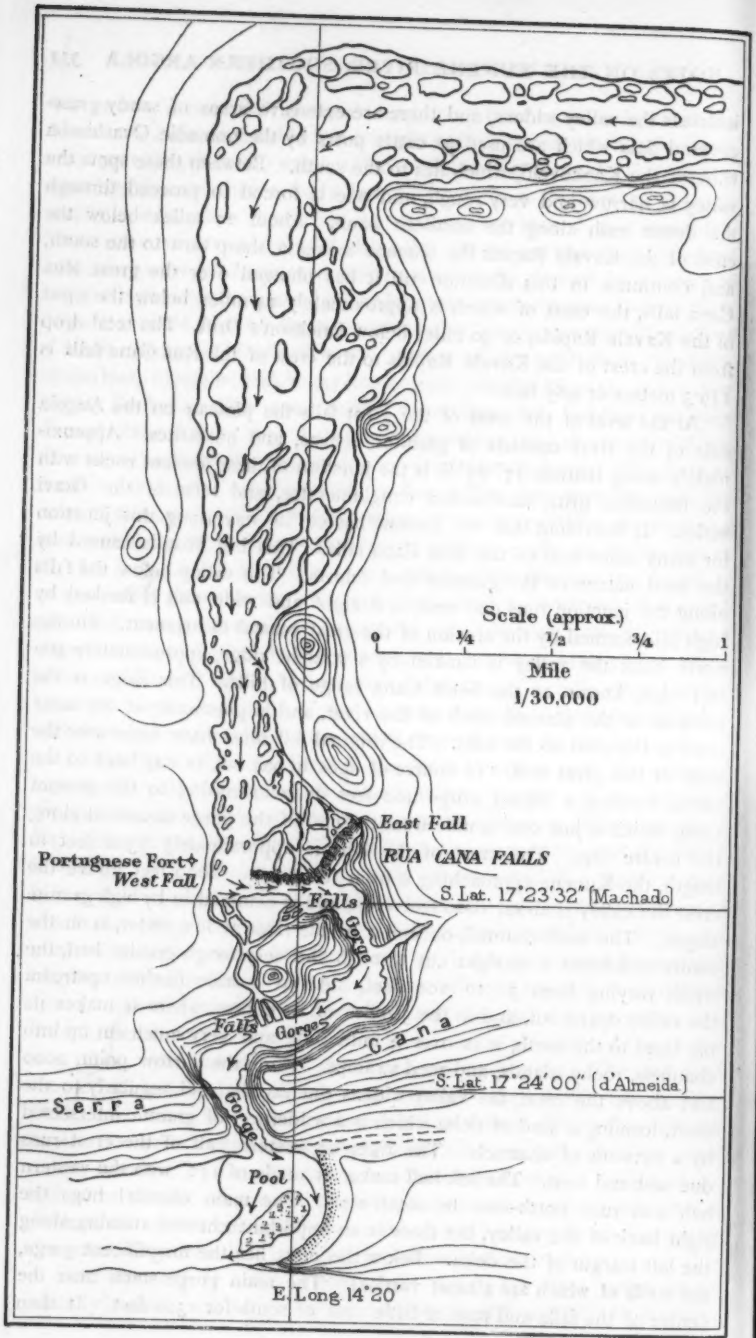
followed by a small fall, the total drop being from 15 to 20 feet. Below the fall the main channel is in a straight narrow gorge, which is, however, of no great depth to the water surface. Below this gorge the river widens considerably, and has a fairly low gradient for a distance of approximately a mile when it reaches the crest of the second and larger fall. There are here several parallel channels. There are two large high-level channels on the left bank separated from the main channel by a long and straight high ridge, composed of schist and various igneous rocks. This ridge is covered with an almost impenetrable jungle, composed mainly of a small species of Euphorbia and masses of the very sharp *Sensivera Cylindrica*, together with many large trees, chiefly Mopani, and a few mighty Baobabs. The main channel below these falls has been cut deep through the red grits into the underlying schists, and the trough of the river now presents the appearance of a deeply cut gorge. The drop at these lower falls is approximately 20 feet. The total drop between the crest of the upper fall and the tail water of the lower fall is, according to levels recently taken by the Portuguese military engineers, 11·82 metres or 38·4 feet. From the edge of the main valley the country, which is covered with dense forest, chiefly Mopani, and is composed of the red grits and conglomerates and calcareous tufa (derived from the former) rises some 50 to 60 feet to the sandy plateau level in 1200 yards. This series of falls and rapids, spread over a distance of a little over a mile, form the "small cataract" of the German-Portuguese boundary dispute, and should be designated by the native name Kavale Rapids or Falls.

Below Kavale the gradient of the river increases, and the valley is cut steadily deeper below the surrounding country of the plateau. Erosion near the valley margins has given the country a hilly appearance for some miles on either side, especially on the south side; and the valley is flanked by a chain of kopjes, mostly densely wooded. About a mile below the Kavale Rapids the valley is from one-half to three-quarters of a mile in width. The higher levels are throughout composed of the red grits and conglomerates, but the lower levels are now wholly composed of greenish or red schists. About 5 miles below the rapids the gradient flattens near the junction of the schists and the underlying granites. A little further down the river is confined to a single channel, which, at the time of my visit (end of July), was about 100 yards wide. The bed consists of shingle, and is smooth and regular. This is the Chimbombe Drift, which forms a very easy crossing at low water. Below this drift the river is flanked on the left by the Okahe hill, the flank of which rises steeply above it. The Kunene now descends through a height of 21 metres or 68 feet at the Chimbombe Rapids which are spread over a distance of several miles, the river throughout being split up into many channels. The river-bed is granite and other igneous rocks.

For the next 12 miles below these rapids the river maintains a westerly course, and is a succession of pools and rapids. At frequent

intervals the valley widens, and there are extensive areas of sandy grass-covered flats which are used as cattle posts by the nomadic Ovashimba tribe of the Kaokoveld, which lies to the south. Between these spots the valley is narrow and very rough, and one is forced to proceed through the dense bush along the southern bank. About 20 miles below the crest of the Kavale Rapids the Kunene makes a sharp turn to the south, and continues in this direction till it has plunged over the great Rua Cana falls, the crest of which is approximately 24 miles below the crest of the Kavale Rapids, or 30 miles below Erickson's Drift. The total drop from the crest of the Kavale Rapids to the crest of the Rua Cana falls is 149·3 metres or 485 feet.

At the level of the crest of the great falls the plateau on the Angola side of the river consists of granites, schists, and quartzites. Approximately along latitude 17° 25′ S. is the junction of these ancient rocks with the felspathic grits, sandstones, conglomerates, and tufas of the Otavi series. It is evident that the Kunene has cut its way along this junction for many miles west of the Rua Cana falls. This big drop is caused by the hard nature of the granites and schists. The valley below the falls along the junction runs due west, is straight and wide, and is flanked by high hills formed by the erosion of the great coastal escarpment. On the north bank the valley is flanked by a straight ridge, approximately 400 feet high, known as the Serra Cana range of hills. This ridge is the remains of the plateau north of the river, and is practically at the same level as the crest of the falls. The original fall must have been over the edge of this great wall. In course of ages it has cut its way back to the north, forming a zigzag gorge 400 feet deep extending to the present crest, which is just over a mile from the end of the gorge measured along the centre line. The crest of the falls is approximately 2300 feet in length, the Kunene approaching it from the north. 2000 feet above the crest the valley is about 1000 feet wide, and is hemmed in by high granite slopes. The main channel, occupied by the river at low water, is in the centre and forms a straight cut through the very rough granite bed, the width varying from 50 to 100 feet. About a mile further upstream the valley opens out, and in the 3 miles of its course, where it makes its big bend to the south, it is over a mile wide and very much cut up into channels, rocky islands, and reed swamps. From the narrow point, 2000 feet above the crest, the valley widens out rapidly and regularly to the crest, forming a kind of delta which is a wilderness of granite intersected by a network of channels. The right or western half of the crest runs due east and west. The left half makes an angle of 120° with the western half and runs north-east to south-west. The main channel hugs the right bank of the valley, but there is an important channel running along the left margin of the delta. Below the crest lies the magnificent gorge, the walls of which are almost vertical. The main gorge starts near the centre of the falls and runs a little east of south for 1300 feet. It then



Gorges of the Kunene and Rua Cana Falls

THE LOWER KAVALE RAPIDS

THE WESTERN GORGE, RUA CANA FALLS

CENTRAL PORTION OF FALLS OF RUA CANA

EXIT OF THE GORGE THROUGH THE SERRA CANA

turns sharp south-west, and continues in this direction for 2750 feet, and then finally turns through another right angle to the south-east, and in this last length of 1500 feet breaks through the Serra Cana barrier into the broad valley below, running west.

Beneath the gigantic wall under the crest of the falls the gorges run towards the centre, from the western extremity eastwards, and from north-east to south-west respectively, uniting somewhat east of the centre and discharging their combined waters into the main gorge above described. During the flood season the waterfall is continuous from one end of the crest to the other. As the discharge greatly decreases during the winter months, the fall is resolved into a large number of individual falls spread about along the face. The main discharge is, at all times, at the western extremity of the western gorge, and the next in importance is at the extreme eastern end of the fall. At extreme low water all the discharge is concentrated over these two falls, but mainly over the western one. The height of the western fall is greater than that of the eastern fall, the gorge being cut much deeper at its upper end than in the eastern gorge. The latter is much rougher, and has a very steep gradient from north-east to south-west. There are a number of minor falls over the precipices of the long north-east by south-west arm of the main gorge, which are fed by channels spilling round the western end of the main fall.

The position of the Rua Cana Falls has been fairly accurately fixed by the Portuguese military engineers and by the German surveyor Schmidt. The centre of the crest as determined by Col. Roma Machado is approximately lat. 17° 23′ S. and long. 14° 20′ E. The crest of the Serra Cana ridge at the point where the Kunene breaks through it was determined by d'Almeida and is on lat. 17° 24′ S. The longitude does not appear to have been determined. The total height of the falls from the crest to the pool below the gorge is 406 feet, the altitudes being approximately as follows: crest level, 2730; pool level, 2324.

Below the falls the south bank of the Kunene is composed of a vertical bluff, some 50 feet in height, of hard calcareous tufa, the valley being here 1500 feet wide. Above this bluff is a limestone terrace 2000 feet wide, which is succeeded by a high escarpment of the red felspathic grits, and above this again there is an immense plateau of hard tufa. The red grits, etc., referred to, which compose all the higher levels on the south bank, are classed as part of the Otavi beds by the German geologists, and are probably portions of the basal beds of the Nama system which lies unconformably upon the schist formation in the region of the Rua Cana Falls. The grits, etc., are of a carmine to purple colour. The fragments consist of quartz and pink felspar up to three-quarters of an inch in length. The felspar is mainly of microline, but some of orthoclase and of plagioclase is also present. The matrix is partly ferruginous and partly siliceous. There is to be seen every stage of change from the unweathered rock to calcareous tufa, with the secondary calcification of the cementing material. The

above is based upon descriptions of hand specimens by Sidney H. Haughton, geologist, on the staff of the S. African Museum at Cape Town.

Of the Kunene below the falls very little is known. Major Manning, Resident Commissioner of Ovamboland, reached Zwaartboys Drift in 1919 from the Kaokoveld and reported the valley as being cut deep in the mountains and very rough and wild. He was, however, unable to spend any time on the river or to make any exploration up or down-stream. At the Monte Negro Falls or Rapids, the Kunene is said to make a drop even greater than at Rua Cana, but the information about these rapids is very vague. The officers of the Portuguese Boundary Commission hoped to explore and survey them during the latter part of 1920. The length of the Kunene described is very wild and unapproachable, and access is only possible along the south bank. The margins are covered with dense forest and are teeming with big game of every description.

Before concluding I will briefly describe the dispute and the difficulties concerning the international boundary. The boundary line between German South-West Africa and Angola was defined in an agreement between the German Imperial Government and the Kingdom of Portugal, which came into force on 30 December 1886. In terms of this treaty the boundary was to follow the course of the Kunene river from its mouth to those waterfalls which are situated south of Humbe, at the point where the Kunene breaks through the Serra Cana. From that point the boundary was to follow the parallel of latitude through it right across to the Okavango river, and thence follow the course of that river as far as Andara, and thence again due east to the Catima Falls on the Zambesi. Whilst the definition given in the treaty is fairly clear, it had been the subject of a dispute between the German and Portuguese Governments until the occupation of German South-West Africa by the British forces in 1915. During 1916 the matter came up for consideration by the British and Portuguese Governments. The dispute has centred round the precise spot through which the parallel of latitude from the Kunene to the Okavango should be drawn. The Portuguese assumed for this purpose the high point on the Serra Cana ridge immediately above the downstream portal of the great gorge below the Rua Cana Falls (lat. 17° 24′ S.). The Germans, on the other hand, made the somewhat ingenious claim that the parallel of latitude must be drawn through the uppermost of the falls below Humbe, viz. the Kavale Rapids, generally known as the "Small Cataract," some 5 miles below Erickson's Drift and 24 miles above the Rua Cana falls. The latitude of the Kavale Rapids is approximately 17° 17′ S. The rival boundaries were thus some miles apart measured from north to south. As the disputed zone, which by the way measures about 300 miles from east to west, is, in its central regions, occupied by large and warlike tribes, the Ovakwanyamas, there has been considerable friction in the past. Since 1916 a provisional agreement has been come to between the local British and Portuguese administrations under which a belt of country

6 miles in width, measured south of the old mission station of Namakunde, is administered, as a neutral zone, jointly by a British and Portuguese resident commissioner. This agreement was fixed up arbitrarily and somewhat regardless of even such data as were available at the time, as the latitude of Namakunde, as determined by the German surveyor Schmidt, shows that place to be 2 km. south of the boundary line as claimed by the Germans. As the zone throughout its great length and breadth is dead flat, excepting in the length along the Kunene west of Erickson's Drift, and is, to a large extent, covered with dense forest, it is obvious that the limits of the zone are very vague, a circumstance which is a constant source of trouble, worry, and irritation to all concerned.

The settlement of the dispute formed the subject of investigation and correspondence between the British and Portuguese Governments in the years following the defeat of the German forces in 1915, and at the end of 1919 each country appointed a commission to meet on the spot and arrive at a settlement of the dispute. The commissions were composed of the following officers:—

Representing the British Government: Francis Edgar Kanthack, C.M.G., Director of Irrigation for the Union of South Africa, Chairman; Herman Eugene Schoch, Surveyor-General, Transvaal; and Major Charles Nicolson Manning, Resident Commissioner, Ovamboland.

Representing the Portuguese Government: Colonel of Engineers Carlos Roma Machado de Faria e Maia, Commissioner; Luiz de Menezes Leal, Captain of Engineers, Captain Jose Luiz Goncalves Canelhas, Assistants.

The two commissions, after making preliminary investigations on their own account, met and commenced negotiations at the Rua Cana Falls on 30 June 1920, and an agreement concerning the delimitation of the international frontier between Southern Angola and the South-West Africa Protectorate was signed at the Portuguese camp adjoining the Rua Cana falls on 6 July 1920. The agreement remains to be ratified by the British and Portuguese Governments, and until this is done no further details can be given.

APPENDIX.

The spelling of place-names demands some explanation. The spellings shown on the maps have in many cases been taken from Portuguese sources, and are often very much mutilated versions of native names. The great difficulty with the lower Kunene region lies in the fact that the country is practically uninhabited and is only visited spasmodically by the nomadic Ovashimba tribes of the Kaokoveld. A large number of these natives accompanied the Commission as porters, and the headman who brought them is an old experienced hunter with great knowledge of the country traversed. The utmost pains were taken to ascertain the recognized names of rivers, rapids, falls, hills, and the like, and these have been adopted, *e.g.* Kavale, Chimbombe, Okahe, Okarundu, Etaka.

The spelling of the name Erickson is that given by the son of the old trader and hunter who travelled extensively in Ovamboland and southern Angola years ago, and whose name figures frequently on maps of these parts. The son, who is personally known to the present British Resident Commissioner for Ovamboland, informed the latter that his father claimed to be British.

The origin of the names Rua Cana and Serra Cana is not known, but is probably a Portuguese corruption of an old native name. The Ovashimba recognize the name Rua Cana, but have probably learnt it from Portuguese sources.

The description of the bluff or escarpment at the great falls as the "Serra" Cana or Cana Range is most misleading, as it is really no range of hills at all. The term was, however, used in the German-Portuguese treaty of 1886 and in all subsequent official correspondence and has therefore been retained. The Germans called the country between the Angola boundary and the Etosha Pan "Amboland," but I think this term is incorrect. It is locally unknown. It is the country inhabited by the very distinct Bantu tribe of the Ovambo, and is known officially, both to the Portuguese and South African Union Governments, as "Ovamboland," and the term Amboland should no longer be used.

INTERNATIONAL AERONAUTICAL MAPS

Lieut.-Col. E. F. W. Lees, D.S.O.

Read at the Meeting of the Society, 17 January 1921. Maps following p. 400.

THE subject of an International Aeronautical Map was first discussed some nine years ago, when, in September 1911, Monsieur Lallemand read before the British Association at Portsmouth a paper entitled "The International Air Map and Aeronautical Marks." His opening sentence was, "The dirigible air balloon, and more especially the aeroplane, which are to-day scarcely out of the period of research and experiment, will soon enter the area of practical politics. It is time that aviators were given means for finding their way similar to those which, for a long time, have existed for navigators and travellers." No definite progress towards the establishment of International Air Maps had, however, been made when the war broke out, and during the war the question was naturally in abeyance; various types of special maps, adapted for the uses of airmen, were published by different nations, but these maps were in no sense international.

Within a year after the armistice, in October 1919, a convention was signed in Paris by some thirty nations and states. This convention laid down the regulations for aerial navigation, and, in an annex, recognized the need for an international series of aeronautical maps, and established certain general principles. These principles embody certain of the proposals which M. Lallemand put forward in 1911.

In this annex it is laid down that there shall be two series of international air maps: one series, to be known as General Aeronautical Maps, is to be on Mercator's Projection, on a scale of 3 cm. to 1 degree

of longitude at the equator, *i.e.* a scale of about 1 : 3,700,000 at the equator, a longitudinal scale of about 1 : 2,000,000 in our latitudes. Certain criticisms have been levelled at the adoption of Mercator's Projection; these will be referred to later.

The second series, to be known as Local Aeronautical Maps, is to consist of degree sheets on a scale of 1 : 200,000; no particular projection is laid down, nor is this necessary. In many countries maps exist already on a scale of 1 : 200,000, and no doubt these maps will be utilized; it must be remembered, however, that in their existing forms they satisfy only imperfectly the needs of the airman.

The annex lays down also:

(i.) that the index scheme for the Aeronautical Maps shall be based on the index scheme for the International 1/Million Map;

(ii.) that the metre shall be the standard of length;

(iii.) that the colours and symbols of the 1/Million series shall be used as far as possible: it will be seen that considerable departures from this proposal are suggested;

(iv.) that, in addition to the customary latitude and longitude notations, the maps shall bear numbers in enclosed rectangles corresponding to a new system of co-ordinate reckoning based on the South Pole and the antimeridian of Greenwich: that is to say, the latitudes commence with the South Pole as zero, and increase northwards to 180° at the North Pole, and the longitude commence with the present 180° as zero and run eastwards round the sphere to 359°. By this system the employment of the letters N. and S. and E. and W. is avoided, and an index number can be given to any sheet based on the co-ordinates of its south-west corner. It should be noted that, under this system of indexing, certain general and local maps will bear the same index number, and that it will therefore be necessary to employ the prefix General or Local when demanding aeronautical maps;

(v.) that each sheet is to be given a suitable geographical name.

The annex finally gives a summary of the details which are to be shown on the sheets of each series, and establishes certain conventional signs. These signs have not in all cases proved entirely satisfactory, and alterations are suggested. Additions have also been made: no symbol, for instance, was laid down for a seaplane station.

The work involved is immense, and a considerable proportion falls on the shoulders of the British Empire. The Air Ministry were faced with the problem of compiling and producing these maps, with no existing machinery. The problem was solved by an arrangement between the War Office and the Air Ministry, whereby the Geographical Section of the General Staff should undertake the work. This arrangement came into force in April last.

The first work undertaken was the preparation of an index scheme for the general maps. At this point the adoption of Mercator's Projection began to come in for some criticism. Mercator's Projection has always been used for navigation on account of the property that the compass course between any two points is the straight line joining them. The drawbacks are the varying scale, the great distortion towards the Poles (so much so that, for maps of the Polar Regions, it will be necessary to employ some other projection), and the considerable additional expenditure in time and labour in production, owing to the necessity for redrawing the map. One proposal, based chiefly upon the large part which radiogoniometry (directional wireless) will play in navigation, was that a gnomonic projection should be employed: the Great Circle Bearings obtained by radiogoniometry can then be plotted as straight lines. The formula for the conversion of the Great Circle Bearing to the Loxodrome is, however, so simple that the proposal, in view of other drawbacks, did not gain adherents. Another proposal was to employ a modified polyconic projection with rectilinear meridians. This would mean economy in time and labour, as the existing Million Series could be used direct: the scale would be the same on all sheets, facilitating the measurement of distances. But navigation on such a projection involves an appreciable change of direction for the aviator at each meridian: this change will be about $\frac{1}{2}°$ to 1° for 1° of longitude. Navigators, however, strongly upheld the proposal to adopt Mercator's Projection for the general maps, and an index was prepared utilizing this projection. The index is based on the index for the International Million Series. Between 60° S. and 60° N. according to the old notation, or between 30° and 150° according to the new notation, each sheet of the General Aeronautical Series will be 18° by 12° and will contain nine sheets of the Million Series: between 150° and 158° each sheet will be 18° by 8° and will contain 6 sheets of the Million Series. The distortion then becomes very great, and it would appear that north of 158° and south of 30° we should adopt some other projection. Though it may be considered advisable to carry the Mercator Series as far north as 162° in order to include Northern Scandinavia, Northern Canada, etc., the General sheets between 158° and 162° would only contain three sheets of the Million Series. The British Empire will be responsible for the production of thirty-six sheets.

One other point arises in connection with this index scheme, and that is the question of overlap. The value of an overlap for aerial navigation is recognized, and a proposal was put forward that there should be an overlap of 3° both in latitude and longitude. This appeared excessive; some sheets would become unwieldy, and the cost of production of a sheet would be considerably increased, and it has now been agreed that an overlap of 1° of latitude and 2° of longitude, wherever the sheet edge is not in the sea, will meet the needs of the airman.

The question of the design of these aeronautical maps was next taken

up. We are on the threshold of a wide development of cartography for aerial purposes, and it appears desirable that we should endeavour to lay down a basic scheme which shall be logical, feasible, and applicable to all aerial maps, the general map, the local map, and any special maps prepared for aerial purposes. The proposals which are about to be submitted to you have met with general approval, except in one or two particulars, in their application to the local maps, but in their application to the general maps considerable differences have arisen, based on the uses to which these general maps are to be put. One point of view is that the general and local maps are entirely different in purpose, the general maps being for navigation, the local maps to enable the aviator to fix his position by comparing the ground beneath him with his map. The other point of view is that the two series are complementary to each other. The depiction of relief is the question chiefly affected, and this difference of opinion will therefore be dealt with in detail when that question is arrived at.

Terrestrial man has, under normal circumstances, a limited view compared with that obtained by the airman, and his gaze is horizontal. A picture will not be of very great assistance; he wants a great deal of information given him in the way of names, etc.; he has milestones, sign-posts, and his own tongue to help him. The aviator is differently situated: he has a large area spread out beneath him, his view is more or less vertically downwards, and he is therefore materially aided by a picture: he does not require much in the way of names, but he does want the characteristic geographical features and all artificial features of special value as guides to stand out clearly. Shape is of special value to the airman: terrestrial man walking along a road, railway, or river which curves about a great deal, does not appreciate the relative values of the curves; the airman does—so much so that he can locate his position by these relative values. Our design must therefore be a logical one, controlled by the values which the aviator places upon the various objects seen from his machine.

The aerial map can scarcely show too much detail, provided there is no suspicion of overcrowding: the limitation of names renders this easier. The exact position and shape of railways, roads, rivers, towns, etc., must be shown as far as the scales employed will allow. On the local maps on a scale of 1 : 200,000 a large amount of detail can be shown, so much so that an airman, who gets in bad weather only a fleeting glimpse of the ground, should be able to locate himself. The scale of the general maps permits only a selection of the detail to be shown, and this selection must depend on the value which the airman places on objects as guides to his position or to course.

The conventional signs must also be based on this value. For instance, among the conventional signs laid down by the Convention is one for telegraph wires consisting of large red crosses: these will stand out in a

most conspicuous manner overshadowing other detail. Whereas in close country the airman will not see the telegraph lines, in open or arid country on a sunny day he may pick up the shadows of the posts, but these shadows will not dominate the landscape. Telegraph lines must be shown, in so far as this is possible without overcrowding the map, as such lines may afford a valuable indication of his whereabouts to the airman, but a conventional sign must be adopted which gives to a telegraph line its correct value from the airman's point of view with reference to the other objects depicted on the map.

Our object must therefore be to obtain a map which shall be clear, which shall be, as far as in our power, a fairly good picture, and which shall give to objects on the ground the value which the aviator places upon them.

For a picture a ground colour is necessary, and it is suggested that a pale green should be used for cultivated ground or ground covered with vegetation, a pale buff for arid ground: in addition to getting a base for the picture, valuable information is provided by this means in many parts of the Empire. To this proposal some objections have been raised. The first is that the ground tint varies according to the season of the year: it is agreed that this seasonal variation is difficult to cater for, but the areas in which a prevalent tint is difficult to arrive at are, taking the world as a whole, limited, and it should be possible to overcome this difficulty. Secondly, that the pencil lines used in plotting a course do not stand out as they would on a white ground: this objection was withdrawn after actually plotting a course on a manuscript map with ground colours. The third objection is that a layer system to indicate relief cannot be employed with a ground tint: this is agreed to, but the employment of a layer system is not advocated.

The maps being primarily aeronautical, we may take it that the provision of aeronautical information in a conspicuous form must be our first care. Black on a map is more conspicuous than any other colour; it is also easier to disassociate black from colours than one colour from another. The aerial information will therefore be in black, and will include the positions of aerodromes, sea-plane stations, and ports of entry, the heights of mountains and passes, the positions of aerial and marine lighthouses, lightships, and wireless stations, and any natural or artificial features which are too small to be represented to scale on the map, but which may be of value to the airman.

Water, always a most useful guide to the airman, will be represented in the conventional blue, in the conventional way, except that swamps, etc., will be shown in blue stipple.

Having decided upon black for all aeronautical information, and blue for all water, the next most conspicuous colour, red, must be used for the objects upon which the airman places the next greatest value. It is considered that railways come next in the airman's picture: in France and

Italy it is said that the roads are of more value than the railways, but taking the world as a whole, this does not apply. Railways are not confusable with other objects, and they are accurately surveyed as regards shape, although their location may be faulty in badly mapped countries: accurate shape, and the accurate plotting of junctions, curves, etc., are invaluable to the airman as guides to his position. Railways go fairly directly from one town to another, having been built to serve the needs of those towns, and the towns they serve are the important towns of a country and therefore normally the objective of the airman both in peace and war: they can be followed both by day and by night in clear weather. In unsettled or sparsely populated countries railways are of the first importance: they afford not only a means of obtaining supplies of petrol, oil, and food, but a probability of obtaining assistance in the event of a forced landing.

Dealing with roads, to the airman roads of any class, first, second, or third, appear much the same. The earth is covered, in highly settled districts, by a reticulation like the workings on a hot-house melon. The main road may be conspicuous by reason of its directness, or as the backbone of a system of roads; but all roads, when wet, muddy, or tarred, tend to merge into the landscape and lose their individuality: on a railway in use, in fine or wet weather, there is always the shine on the metals. In many parts of the world roads are anything but accurately surveyed.

It is proposed, therefore, to consider the railways as being of more importance to the airman than the roads, and to show them in red: on the general maps by a single red line; on the local maps a single line of rail will be indicated by one red line, a double line by two red lines, three pairs of rails or more by the two lines blocked in. On the general map it will be possible to show practically all railway lines: if roads are adopted as being of more value to the airman than railways, only some roads and some railways can be shown, and an untrue picture is arrived at. As it is, one detail of the map, railways, is complete: such roads will be shown as the scale permits.

Towns and villages stand out well, and when, as in the local maps, it is possible to show their shape and main arteries, they are most useful guides: it is proposed to indicate them in red. Railways, towns, and villages being indicated in red, it appears sound to propose that all artificial structures, other than those which come under the heading "Aeronautical Information" (lighthouses, lightships, conspicuous guiding marks, etc.), or the heading "Waterways" (canals, etc.) shall be indicated in red: telegraph lines, light railways, tramways, electric power cables, etc., will therefore be shown in this colour.

Roads will be shown in a deep yellow or burnt sienna: if the latter colour is to be used, great care must be taken that it approximates in no way to red.

Woods will be in the conventional colour, green, but not too con-

spicuous a green, as the airman must not rely too much upon the exact outline of woods as an indication to his position. A map cannot be kept sufficiently up to date to show new clearings in, or additions to, woods: a young plantation may be just as conspicuous as a well-established wood.

To sum up, it is proposed to show, on a pale green or pale yellow ground: aeronautical information in black; water in blue; all artificial structures in red, except those which come under the headings "Aeronautical Information" or "Waterways"; roads in deep yellow or burnt sienna; woods in green. Criticism has been levelled at the proposed colours of railways and roads: the counter-proposals are to show the railways in black and the roads in red.

With regard to the railways it is claimed that they are so important to the airman that they should be treated as "aerial information" and indicated in black. None of the aerial information, to be shown on the map, takes the form of a long black line: moreover, black is the conventional colour laid down for the International Million Map. Railways in black have been tried: the result on the map was an immediate loss, in highly civilized countries, of that which we are striving to obtain—absolute clearness for the aeronautical information. As time goes on, there is no doubt that the maps will be heavily loaded with aerial information, especially in the shape of ground marks. At many railway stations the name will be painted on the roof: a railway in black will not show up among these ground marks in black, a railway in red will. It is agreed that the indication of the number of pairs of rails is of value to the airman: if black is employed, a long length of "three or more" pairs of rails will "kill" the neighbouring aerial information, a short length will approximate to the conventional sign for an aerodrome. With regard to the argument that the conventional colour is black, it is agreed that this is so on the majority of maps, but it appears to be most undesirable that we should be bound by convention. Maps exist at present for those who travel on land or sea; now a start is to be made on the maps for those who travel by air, and these maps must be based, not on the conventions, but on the requirements of the airman.

The proposal to show roads in red is based on convention, although, whereas railways are largely shown in black, many instances of roads in colours other than red can be adduced. Again, it is urged that convention should be put aside. It is also argued that roads are just as much artificial structures as railways. This is hardly correct: in very large areas of the Earth roads are artificial only in the sense that man has cleared away the tree-stumps or boulders. There is also this difficulty in connection with the indication of roads in red: it is generally agreed that towns and villages are to be in red, and that the main arteries of a town or village shall be shown. This cannot be done with roads in red: the indication of a village consisting of a single row of houses on either side of the road will be impossible. It has been suggested that this difficulty might be met by

leaving the roads white in the towns and villages, but the result would not be satisfactory in the case of long villages on either side of a road: the effect is that of a road splitting into two and joining up again. Red will give the roads too much importance in the picture, especially as the railways will have lost their distinctiveness owing to their being in the same colour as the aerial information. There are many maps which show the effect of accentuating the roads in red.

It is suggested, therefore, that the depiction of the railways in red and the roads in yellow or burnt sienna will enable us to more nearly satisfy the requirements of the airman than the proposal to show railways in black and roads in red.

There is still one question of great importance to be considered, and that is the question of the indication of the topographical relief. With regard to the Local Maps, there appears to be a general agreement that some form of hill shading shall be employed: this is in accordance with the Convention. With regard to the General Maps, there is no such general agreement: two camps have formed, one advocating the employment of a layer system, involving, of course, no use of ground tints, the other advocating the employment of hill shading with ground tints. Again, the Convention supports hill shading.

The advocates of the layer system put their case thus: the General Map is primarily a map for navigation purposes, the Local Map is a map by which the airman fixes his position by comparing the ground beneath him with his map. The two series are entirely different in purpose, and there is, therefore, no objection to the employment of a different design. While agreeing to a system of hill shading for the Local Maps, they propose a layer system for the General Maps: a layer system, more than any other system, enables a navigator, on plotting his position and finding himself in the neighbourhood of an obstacle, to decide rapidly (and rapidity of decision is essential in view of the great speed at which aircraft travel) whether to cross the obstacle by climbing without the prospect of getting into further trouble on the other side, or to turn to port or starboard with the object of going round it. Moreover, when planning a flight, the navigator can select and plot his proposed course with greater ease on a layered map: a map on these lines will contain little aeronautical detail, and will be used in conjunction with "Instructions to Airmen" and "Lists of lights and ground marks." The layer system proposed is as follows: ground below 1500 feet, in white; then three shades of brown to represent ground below 3000 feet, below 6000 feet, and below 9000: above 9000 feet, white again.

The advocates of hill shading cannot agree that the General and Local Maps differ in purpose: they consider that the two series are complementary to each other, and that the General Map should show as much detail as the scale permits, the Local Map amplifying this detail. The design of both series should therefore be the same.

It has been found by actual drawing that the General Map can be made to give clearly a very large amount of the information required by the airman, provided a system of hill shading is employed. In many parts of the world it will be possible to show all the available detail on the General Map, and therefore on long flights there will be a big saving in the weight of maps to be carried, caused by the fact that, having the General Map, it will not be necessary to carry the Local Map. Again, it will be many years before Local Maps will be available for considerable areas of the Earth's surface: in many instances it will not be worth while producing Local Maps on account of the paucity of detail, and therefore the General Map will be the map which the airman will be compelled to use. The map must therefore be designed for the general purposes of the airman, and not with the primary object of depicting relief.

The tendency will be for the airman to use his General Map in preference to his Local Maps. On the main flying routes he will get to know his route as the motorist knows his road, and the General Map will serve his purpose, if carrying as much detail as the scale permits: if in difficulties he may turn to his Local Map, and he will certainly *not* be assisted by a different design. Moreover, in an aeroplane travelling at a high rate of speed, a change of Local Map might be necessary every seven or eight minutes. The airman will be materially assisted if his General Map is good enough (and it can be made so) to obviate this constant changing of sheets: even if he is flying by local sheets, because he does not know the route and the country is full of detail, or because he is only getting fleeting glimpses of the ground, he will rely on his General Map to take him over the corners of sheets, and he will not want to jump from one design to another.

The airman is committed already to the use of two series of maps: the advocates of the layer system propose that, in addition, books of reference should be employed. In a dirigible there is a table for the maps and a shelf for the books; in an aeroplane there are no such facilities. The maps must carry such information as the characteristics of aerial and marine lights, and the position and nature of wireless stations, ground signs, etc.: books must be consulted before the airman leaves the ground.

Dealing generally with the question of "layers *versus* hill shading," it is claimed that hill shading gives a truer picture of the ground, and that the airman receives material assistance from a picture: the layer system gives an unreal impression of a sudden jump in height from one layer to another. Moreover, a layer system gives too much importance to the relief of the ground; the other detail on the map is overpowered; among the darker shades of brown detail may be obscured. Again, ground covered by wadis or nullahs or cut up by low precipitous hills cannot be indicated by a layer system, and such information is of great value to the airman. No system of relief can give an airman an actual spot to land,

but by hill shading, the areas which offer the best chance of landing can be indicated.

There is also this point to be remembered: in the International 1/Million Series we have, or shall have, maps on which the layer system is employed. In flights involving the crossing of mountainous country, these sheets can be consulted beforehand, and, if necessary, carried: the General Aeronautical Maps will show clearly which sheets of the International Million Series are involved.

With reference to the actual system of layers proposed (white below 1500 feet, shades of brown to denote ground lying below 3000 feet, 6000 feet, and 9000 feet, and then white again above 9000 feet), it is agreed that, on the scale of the General Maps, it is not possible to have the layers at a smaller interval than those proposed, and an indication of change of ground-level limited to 3000 feet is not of real use to the airman. Many important features will not be indicated; for instance, a range of hills running up to 2000 feet above a plateau whose general level is 3500 will not be shown, except by spot heights in black: these spot heights may equally well mean that the ground slopes gradually up to these heights, and the airman will get an erroneous idea of the country. The advocates of the layer system propose to introduce contours or form lines to meet this difficulty. The colour used for these contours or form lines will have to be deeper than the deepest shade of tint to be employed, and the map becomes still more overloaded with the depiction of relief to the exclusion of other detail. Contours in any case will not be of assistance. They cannot be interpolated at a small-enough interval to show any detail of the ground. How the ground above 9000 feet is to be dealt with has not been stated. Hill shading has been suggested, but if it is agreed to use hill shading for these areas, which would appear to be most important in view of the heights at which aeroplanes fly, why not use hill shading for the whole map?

The balance of the argument appears to be in favour of the advocates of hill shading, who wish for similarity of design in the two series, and who do not think that the layer system proposed will give a sufficiently good indication of the ground. There is still the question of the actual navigation of aircraft. It is claimed that this is easier on a layer system than on any other, but hill shading and spot heights would appear to suit the aerial navigator equally well. By hill shading mountain masses and difficult country can be clearly shown, and avoided if necessary; otherwise the spot heights will give the airman the information he requires. In fog, in bad weather, or at night he will climb well above any spot height in the neighbourhood of his estimated position. If he has to come down under these circumstances, he will take to his local map (which is hill shaded) in the hope of picking up some little bit of detail as a guide to his position.

The three controversial points in connection with the Aeronautical Maps are therefore:

(1) Whether Mercator's Projection is the most suitable projection for the General Maps.

(2) Whether hill shading with ground tints or a layer system shall be employed on the General Maps for the depiction of relief.

(3) Whether railways shall be shown in red and the roads in burnt sienna, or the railways in black and the roads in red.

Except on these points, the proposals which have been put forward have met with fairly general approval; it is, however, worth while running through the conventional signs in detail: there are points which require explanation, and certain signs have not so far been referred to.

As already stated, *forests and woods* will be shown in green; orchards will be indicated by green dots in regular lines where the scale permits; with regard to country covered by small orchards, vineyards, hop-fields, banana plantations, etc., the airman not only may get an idea of his whereabouts from their indication on the map, but he must also be warned off them. It is suggested that this information can be most suitably conveyed by lettering on the serial information plate. A mangrove swamp will be a green stipple on a blue ground.

The indication of *water* requires no comment; the use of a blue stipple for swamps, etc., has been referred to; areas liable to inundation will be shown by a blue stipple to warn airmen off them; when such areas afford good landing grounds at certain times of the year, a note will be made in black on the serial information plate.

Railways have already been discussed. A *light railway* will be shown as a single red line with the letter L in black; a *tramway* in the same way with the letter T in black; when the light railway or the tramway runs along a road, the black letters only will appear: in both cases departures from the road must be clearly shown. It is not proposed to distinguish overhead electric railways and tramways; an airman, in the event of a forced landing, will endeavour to keep clear of anything red as long as he is in a position to use his map; then he uses his eyes *Railways under construction* will be shown by dotted red lines.

Overhead power lines will be indicated by the symbol for telegraph lines with the addition of the letter P in black.

With regard to *roads*, in the Convention it was laid down that a distinction should be made between "very visible" and "less visible" roads; this proved to be unworkable, and no attempt has been made to apply this distinction. *Tracks* will be dotted.

Sandy desert and *sandbanks* will be indicated by a brown stipple; sandbanks are shown up well by this arrangement. The 10-*metre bathymetrical line* will be shown in blue, where the indication will be of value to the airman.

With regard to the *lettering*, other than Aerial information, this will be in black, in a different style to that employed for the Aerial information, and will be very limited.

With reference to the Conventional Signs for Aerial Information:—

Aerodromes and Emergency Landing Grounds.—The true shape and orientation will be shown; when this is not known, they will be shown as circular. No sign was laid down for a *Seaplane Station* in the Convention; the one shown is suggested, and combines well with other aerial information.

Wireless Telegraph Stations.—It is suggested that, when small and isolated, this symbol may bear a resemblance to a square; and a proposal is under consideration to use three arms at an angle of 120°. The method of distinguishing between the different forms of wireless and directional wireless has yet to be decided. The International Hydrographic Conference has adopted symbols for five different kinds of stations, but there are more than five to be provided for, and the symbols adopted are not altogether suitable for our purpose.

Aerial Lights.—When the light is at an aerodrome, the circle will circumscribe the aerodrome.

Marine Lighthouse.—This is one of the Admiralty symbols, except that the star is five-pointed instead of six-pointed. The sign for two or more lights in close proximity, such as harbour lights, is a new proposal; such lights are often a useful guide to the airmen, and the stars were found to take up too much room.

Light Vessels and Light Buoys.—There has been a great deal of discussion over these symbols; it seems desirable that the decisions of the International Hydrographic Conference should be adhered to, and the British Admiralty signs (a boat in elevation and a buoy in elevation) adopted. These signs are, however, unwieldy and take up too much room; in well-lighted waters the configuration of lights is not immediately or easily grasped; they are in elevation, and the airman sees objects in plan. The actual position of the light is indicated by a small circle on the water-line of the symbol, whereas the eye is caught by the star, representing a light, which appears at the top of each symbol. In crowded waters there are difficulties in showing the characteristics of the lights. The symbols shown are therefore proposed, and a comparison of two maps, one employing the Admiralty symbols, the other employing the proposed symbols, has resulted in favour of the proposed symbols. Light-buoys will not usually be shown, as they resemble closely the lights of fishing-vessels, but there are places, especially abroad, in which the indication of a light-buoy may be of value to the airman.

International Boundaries have been treated as aeronautical information; they involve customs, and are the boundaries of potential prohibited areas. The symbol suggested is more easily handled on a complicated winding boundary than that laid down for the International Million Series.

Heights.—The Convention proposed that the figures indicating heights should be surrounded by an oval ring; this was unsatisfactory, owing to possible confusion with ground marks. Now it is proposed that a black

triangle and dot should be used; but this is the symbol for trigonometrical heights; the heights on the aeronautical maps are shown only to the nearest 100 metres above the actual height. A dot with a number on either side stands out sufficiently well, and we do not run into double figures on the left-hand side of the dot. It has been suggested that a cypher should be shown on the left of the dot when the height is under 1000 metres, but the single number shows clearly the ground under 1000 metres, and this indication may be of value to the airman.

Aerial Corridor, or port of Entry. This symbol is not altogether satisfactory; it will be difficult to use on the general map when the aerial corridor is narrow or when aeroplanes are ordered to cross a boundary at a certain town or aerodrome. We may get a black mark looking at first sight like an aerodrome; two half-arrows, which can be combined into one arrow if necessary, would meet the case better.

Symbols in combination.—So much of the aeronautical information comes all in one place that this fact was one of the controlling factors in designing the symbols. It will be seen that they combine fairly well.

Isolated or Conspicuous Features call for no comment. It is intended that these features shall be indicated only when they are isolated or predominate over other features in the landscape to such an extent as to form valuable guides to the airmen. A gasometer in England, for instance, will not be of much value; most towns have them. On the other hand, such a feature as the Dashwood Memorial in Buckinghamshire might be a valuable guide to an airman's whereabouts.

Abbreviations for Descriptions of Lights.—The airmen must be saved any necessity for consulting books, and the characteristics of marine and aerial lights must therefore appear on the maps. An international scheme has been worked out, and applied to some hundreds of lights with success. Some examples are shown.

Finally, it is necessary to say that the very considerable expense of producing maps on the lines of these proposals is recognized, and no doubt it will only be possible to build up these maps gradually to their final form, producing meanwhile provisional series in, say, three colours, to give the airman some means of finding his way about. But it does seem to be most desirable that we should endeavour to establish a detailed scheme at the very start, in order that there may be no haphazard adoption of colours and symbols as the work progresses.

Before the paper the PRESIDENT said: I have much pleasure in introducing to you Colonel Lees of the Geographical Section, G.S., who is responsible for the construction of the maps for Air Services, and especially for the International Aeronautical Map now under consideration.

Colonel Lees then read the paper printed above, and a discussion followed.

Colonel E. M. JACK: I have one or two small remarks to make upon Colonel Lees' paper. I should like to repeat his emphasis on the fact that any

opinions offered are quite personal and unofficial. I think that the question may be asked why so many proposals contrary to the arrangements of the Convention of 1919 are being put forward by us. The fact is, the British have done more work in preparing these maps and getting out the scheme than anybody else, and we have come up against all kinds of practical difficulties in applying rules laid down by the Convention, and that is the justification for the various proposals for change which we have put forward. The Convention should have laid down principles and not dealt with details at all. As a matter of fact, they did go into detail in several respects, and the details that they laid down have been found in many cases rather difficult to apply. As to the points raised in the paper, I should first like to remark that the decision arrived at by the Convention to introduce a new system of co-ordinate reckoning is, in my opinion, an unfortunate decision and one which is likely to produce a great deal of confusion. We shall always have to say, if we use that system, whether we are using the new or the old. The old system of latitude north and south of the Equator (that is the system based on the Equator and the meridian of Greenwich) is sanctioned by very long usage, and it is quite adequate, I think, and perfectly sound. I cannot see that any practical purpose is served by this proposed new method of reckoning. It may appeal to the theorist, but I cannot see that there is any practical good in it. With regard to Mercator's projection, it was of course evidently decided on in accordance with the views of navigators. There are certain disadvantages, one admits, in Mercator's projection, but it must have very solid advantages to navigators to have lasted for so long a time. It cannot be due entirely to conservatism that it has been used for all these years, and it seems to me that, although there are admittedly certain disadvantages, it is perfectly sound to adopt it. The disadvantage that it is inapplicable beyond a certain point north and south of the equator does not seem to me very weighty, because flying in the Polar regions is not likely to be very common. The chief disadvantages are the expense and labour of having to re-draw so many maps. The question of the system of relief is the most important of the debateable points. It is rather unfortunate that airmen seem to be divided in their opinion on this subject. It is not a question of nationality at all, because you have advocates of both systems on either side of the Channel, but as a matter of fact I think I am right in saying the majority of our airmen advocate the hill shading, and the majority of foreign airmen the layer system. I do not know whether I am biassed on the question. I came to the Geographical Section recently after this matter had been discussed a great deal, and it seems to me that the arguments advanced in favour of the hill shading are very sound. It seems beyond question that what the airman wants is as good a picture of the ground as possible, and I do not think for the particular purpose of the airman that the layer system can give the same picture as the method of hill shading. Of course many points come up in connection with this question, but perhaps the most important is that question of showing hill features in the large intervals which occur between one layer and another. As Colonel Lees showed, the intervals between the layers on these small-scale maps must be 3000 feet, and the fact that this cannot be shown satisfactorily on a layer system seems to me a very strong argument. It would be interesting if any Air Officer here would give his views about that. It seems to me that is a very strong argument in favour of the hill-shading method. As to railways and roads, there again I think the reasons put forward for the colours we propose are sound, but I do not think it is anything like so important as the question of relief, and personally I should be inclined to compromise on that question if by

so doing we could get the hill features shown in the way we think best. I should be quite prepared to agree to showing the railways in black and the roads in red, which I think is what the French in particular want, and it has occurred to me the following solution might be found. Colonel Lees explained to us that the most important thing in the air map is the aerial information, and for that the most conspicuous colour, black, was chosen; while red, the next most prominent colour, was taken for other artificial information. But red, though less strong than black, is a most conspicuous colour, and if we were to reverse the system and use red for aerial information and black for other artificial features, we should preserve the clarity of the map, and at the same time conform more to the Convention and also meet the objections of the French and other people who are very anxious to have railways in black and roads particularly in red.

The FRENCH AIR ATTACHÉ: Colonel Lees has explained very clearly the different points of view. I must say we perfectly agree in the question of the local maps; and even in the question of the railways in red and the roads in black we are not so obdurate as we are supposed to be, because I have reason to believe that we propose to go half way and accept the British system on that special point. It is all due to the difference in the French roads, which are more conspicuous, because we have long stretches of straight lines, which do not, or seldom, exist in England, so that the roads in France are very good landmarks and in any case much better than here. But anyhow, I think the whole question of the local maps is one on which we are ready to come to an agreement. The question of the layer or hill-shading system is different, being one of principle: I mean that the adoption of one or the other depends on the use of the map itself. For local maps which are to be used in direct comparison with the land, the hill-shading system seems to me to be obviously the better; but for general maps, and this is the point, we do not think that they must be a picture of the ground; they are intended, as we think, purely for navigating. In consequence one must be able to put bearings on this map, and we further think (reserving the question of unknown countries) that we shall never use in our countries the general map for a direct comparison with the ground. As I said before, the general map seems rather to be used for preparing a voyage or for putting position lines or any geometrical information on it (azimuths, bearings, etc.). According as this point of view is adopted or not, so the question of hill shading or layer colouring bears relation to it, the latter system being less picturesque and descriptive, but much more accurate for the correct preparation of an aerial journey and the laying out of a safe course. I do not pretend to say which is right or wrong, I have simply tried to express in a few words the real reason for a difference of opinion which does not arise from an "æsthetic fancy" but from a basic difference in principle on the use of the maps themselves.

Colonel H. ST. L. WINTERBOTHAM: Colonel Lees mentioned that there were three points remaining open for discussion—the question of the colours of railways and roads, layers *versus* hill shading, and the choice of a projection. In the question of the colour of railways and roads, I should think most people would agree that previous convention must go for nothing in comparison with the needs of the airmen, and the arguments given for the red colouring of railways seem to me convincing. Whilst we are on this question it may be of interest that the airmen in France were very keen on showing long straight avenue roads, with a line of trees on each side, as a long wood, by adding two green strips along the margins or by colouring the whole thing in a green band.

Long straight avenue roads would also be met with in parts of Italy, Germany, and elsewhere. As to the question of hill shading *versus* layers, the arguments for hill shading were very ably put, but I do not think the cartographer will agree when Colonel Lees says there would be difficulty in making three layers so transparent as not to interfere with the detail. The layer system as proposed is an extremely simple one, and the heaviest tint of browns should be comparatively light, so that there should not be trouble in making it transparent. I think, however, that the map lover, in listening to this lecture, would approve of the solutions advocated except in the third question, the choice of a projection. The selection of Mercator's comes as something of a shock. Colonel Lees said that the great advantage of it was that upon it the compass course between any two points is the straight line joining them. That is not strictly true. Unless one is equipped with a gyroscopic compass it cannot be true. Here, for example, is a picture of a typical sheet as it would cover a piece of northern Asia. The isogonals are truly perplexing-looking things upon it. The magnetic meridians would not be so complicated. But in this particular sheet the magnetic meridians will converge to some point above the centre of the map. Having no knowledge of navigation I make no pretensions to knowing the ways in which sailors set their courses, but to claim that Mercator's projection is absolutely necessary for the purpose seems to me to want a little amplification. No doubt there are tables in which one may find the corrections to the magnetic bearing at any spot. I am not quite sure why such information should not be tabulated for a more reasonable projection. With regard to the question of the size of sheets, I have no time to go deeply into the subject. It will have to suffice to point out that the area of the sheet at latitude 60 is 1·7 times that of a sheet at the Equator. This difference of size is a measure of the distortion which Mercator's projection must introduce. No doubt the choice of a projection must rest to a large extent with the air navigators themselves, but one cannot but feel that navigation for aircraft may not be entirely the same thing as for seacraft. I take it that the sailor travels generally between ports of call not very far distant one from the other, and that aircraft routes of the future may include very long non-stop flights. In that case, his best course would not be a loxodrome, but a great circle. If then the great circle is equally or more important than the loxodrome, wherein lies the advantage of Mercator? I think Colonel Lees said that the calculation of the great circle on Mercator was facilitated by tables. Apparently then the advantages of Mercator's projection consist largely in the tables which have been prepared for use with it. As I said before, however, if tables may be prepared for one projection why not for another?

Colonel J. WALEY COHEN: I think there is very little to be added to what Colonel Lees has said from the point of view of the Controller of Civil Aviation. After having talked to the pilots when planning the long-distance flights which were carried out last year, both to Australia and to the Cape, the Navigation Department of the Air Ministry inclines for the sake of uniformity (especially as the general map is used in long flights more than the local map) to support the views put forward by Colonel Lees, that the "shading" for all maps is likely to prove the most useful. With regard to the colours for roads and railways, I have not the least doubt that it will be possible to bring into line the slight difference of opinion held in the various countries taking part in the Air Navigation Conference. There is one difficulty one comes across in talking to English pilots, and that is, we do not know in this country what a road means to the mind of our Continental friends, as we have few big

straight main thoroughfares such as theirs, which characterize the Continent. But these maps are intended to be international in the widest sense and to cover the whole World, and therefore one has also to realize that in large parts of the World no road recognizable from the air, or even on the ground, exists at all, whereas the railway can always be distinguished. I understand that some of the pilots who did the Australian and Cape flights found that a road is practically useless as any sort of guide, because in the wild country that they went over even such roads as existed hardly showed up at all.

Captain LLOYD: There are only two points which occur to me after hearing Colonel Lees' paper, and they are both details. The first is with regard to the depiction of the towns. In the slide shown we saw the towns depicted—houses as little circles dotted along the roads and main arteries. I should like to suggest that the towns should be shown more solid and that the main features for the towns should be exaggerated rather than shown truly to scale. I know the objection that exists in the minds of all map-makers to the departure from the true scale from anything, but I should like to suggest that the main features of the town design should be exaggerated within the limits of the towns themselves, also anything in the way of parks or water, and that the rest of the towns be blocked in or closely shaded to make these particular points stand out more forcibly. Another point that occurred to me was the question of the description of the lighthouses. Of course the question of their description is very essential and important, but if you get round a harbour several light-houses, each combining all the eight different letters given at the bottom of the chart, I am afraid it is going to be a very difficult question to get these plainly printed especially when you are dealing with the smaller-scale maps. Colonel Winterbotham has already introduced the point of tree-bordered roads—one which was brought very prominently to my notice by airmen during the war.

Mr. A. R. HINKS: I should like especially to emphasize what Colonel Winterbotham has said in criticizing quite seriously and rather strongly the adoption of Mercator's projection for this general flying map on the scale of half a millimetre to the minute of arc or three centimetres to the degree on the Equator. It does not appear to me that the choice of Mercator's projection is well founded. Navigation of aircraft has some analogy to navigation at sea, but the considerable differences may make such an analogy very misleading, owing, in the first place, to aircraft being very much faster than anything at sea; secondly, because of the necessity of having a map which has to bear some relation to things on the ground; and thirdly, for the necessity of a close relation between the small and the larger scale maps. There is nothing at all analogous to that last in navigation. Navigational charts are on all sorts of different scales. That, I think, is a very important difference. The sole merit of Mercator's projection at sea has been clearly stated by Colonel Winterbotham: the line of equal bearing—the rhumb line—is a straight line, and since the meridians are all straight lines parallel to one another, it is possible to take off the bearing of your loxodrome with the aid of the familiar parallel ruler, which is run over the chart to the compass rose. I think it is the convenience of having a parallel ruler and a compass rose that makes the sailor so keen on Mercator's projection. Now the full simplicity of that method is available only on short courses, over which the magnetic variation is constant, and then the course must be continually checked for the effects of changes in variation of the magnetism in the ship. The variation of the scale of the Mercator chart at sea does not matter very much to the sailor because he goes so relatively slow. In aircraft the case is quite different. The speed is so great and the

determination of drift so relatively difficult, that in any case, I suppose, we could not expect to set one's course within a considerable fraction of a degree. I do not know if you would try to set your course to the nearest half-degree?

Colonel WINTERBOTHAM: One degree, I should think.

Mr. HINKS: With the great speed the compass variation may change very rapidly; with the very rapid change of latitude you would have the continual variation of the Mercator scale soon become very apparent; and as an air-course may be set presumably without so much reference to obstructions as a course at sea, it is much more advantageous to use the great-circle course. On the other hand, calculation must be reduced to a minimum. The airman would not have time to do even the calculations, simple as they are, by those A.B.C.D. tables which the navigator uses, and consequently a map on which a straight line approximates more to the great circle would be a decided advantage. It seems to me that the International Map approximates very closely to those conditions; the great circle course is much more nearly a straight line; and we have to consider that the proposed Mercator map on the scale of 1: 3,700,000 at the Equator becomes in our latitudes (which are, presumably, the latitudes which will be more frequently used) very closely 1: 2,000,000. Now maps on the scale of 1: 2,000,000 have already made considerable progress. We prepared during the war a general map of Africa on that scale, and the American Geographical Society has under way a general map of South America on that scale. Generally speaking, it is a very good and convenient scale, and it is quite certain that no errors upon that map would make the error of taking off the course from one point to another anything like as great as one degree, provided you had a ready means of measuring the deviation between your course and the nearest meridian. So it seems to me that what the International Aeronautical Map requires is not so much a completely new map on Mercator's projection, but a special edition of the 1/ 2M. There is great convenience in compilation and drawing if you have a uniform scale; and the only thing, so far as I can see, one wants to be able to do to persuade the flying man that he can use this map for navigation, as well as he can Mercator, is to provide him with a convenient way of measuring the inclination of the course to nearest meridian without using the parallel rulers and the compass rose as the sailor does. The projection of the International Map has the great advantage that it is applicable to the whole world. It can be fitted together in blocks without any very considerable difficulty, at least up to four sheets. A map on the conical orthomorphic projection, such as the projected 1/ 4M for Asia is very nice if you do not try to go too far south in Asia, but south of 20° one gets into very serious difficulties, and I cannot imagine anything more convenient generally than a uniform map on the scale of 1/ 2M. The advantage of extending the existing 1/ 2M should be seriously considered. The 1/ 2M map of Africa is not at present layer coloured, but the drafts we made for it, which are on a scale of 1/ 5M, have in these specimens been layer coloured, and I think it is quite easy to appreciate the advantage the airman would find from a layer-coloured map, although we have rather more layers here than the three simple ones considered by Colonel Lees. I do not wish to enter upon the subject of layer colour *versus* hill shading, because it is only too easy to see how much there is to be said on both sides.

The PRESIDENT: We should like to thank Colonel Lees very much indeed for his most interesting paper, which has given rise to such a valuable discussion.

Note added by Mr. HINKS:

Following upon the criticisms on the adoption of Mercator's projection made in the above discussion, Colonel Jack very kindly called a meeting at the War Office for further argument of the question. The position then taken up by the representatives of the Air Force was that Mercator's projection, and the problems of navigation associated with it, were throughly understood by the Navy, and that the training of pilots on naval lines was the most satisfactory policy. It might be true that air navigation could be conducted on other projections, but why trouble to learn a new method, when the old was satisfactory enough, and the Geographical Section were prepared to undertake the trouble involved in transferring the general land maps to Mercator's projection? The general map would have to be drawn specially in any case, with the new conventional signs, and it was not worth considering the advantage of being able to use existing maps pending the construction of new. Further attack on such a position seems to be futile. One can only regret that the traditions of sea navigation inherited by the Air Force demand the construction of a land map that will be an offence to the eye of any but a navigator.

THE CIRCULATION OF THE EARTH'S CRUST

Lieut.-Colonel E. A. Tandy, R.E. (Survey of India)

Read at the Afternoon Meeting of the Society, 14 *February* 1921.

1. Isostasy.

THE crustal movements I propose to discuss are those connected with the well-known theory of Isostasy. I believe that the theory of these movements can be so developed as to explain all the salient facts of the Earth's crust. We will therefore begin by considering how the idea of these movements has arisen, before going on to my own further suggestions.

Isostasy is based on the idea that a heterogeneous planet would naturally be "bulged where the matter is light and depressed where it is heavy."* It therefore supposes that there is everywhere the same amount of matter under equal areas, so that the matter must be denser under depressions than under elevations.

If Isostasy is a normal feature of the crust, with equal quantities of matter everywhere, it has been recognized that it would soon cease to be so, in face of the continual transfer of surface material in constant directions by weathering, erosion, etc. So that in order to maintain a condition of Isostasy, we have to suppose that these surface movements are balanced by the return of matter underground from areas of deposit to areas of denudation.

* *Vide* C. E. Dutton, on "Some of the Greater Problems of Physical Geology," Phil. Soc., Washington, *Bulletin*, vol. 11 (1888–91), pp. 51–64. This was the first introduction of the term "Isostasy," and also shows that the theory itself dates back to Babbage and Herschel, a century ago.

The obvious mechanism suggested to explain this process supposes the crust to be very responsive to changes of load, so that as further loads are imposed on an area of deposit it sinks to a corresponding extent, thus driving the plastic matter of the sub-crust towards the elevations and other areas which are being relieved of surface load. This sub-crustal movement in a reverse direction to the surface transfer is known as the "undertow." It has so far only been considered as acting in rather a vague and indeterminate way.

My own ideas are chiefly based on a far more lively conception of this process. I propose to describe the whole movement, above the surface and below it, as the Circulation of the Earth's Crust, because I am supposing this movement to be a universal characteristic of the crust, and the ultimate cause of all the great changes in its surface. I would also regard this Circulation as acting in the most detailed manner between every adjacent elevation and depression.

Now most theories of the Earth's crust seem to land their followers in a quagmire of contradictions; whereas Isostasy is clear and simple so far as it goes, and in accord with the main facts of crustal density as disclosed by geodesy. Also this idea of gradual sinking under deposit and rising under erosion is most definitely confirmed by thousands of geological data, and there seem to be none which are clearly against it. The theory is, however, still too incomplete to be of much use to the practical geologist, and my present object is to try and advance it a further stage in its development. Before embarking on this argument it will be necessary to refer to certain physical facts in regard to which present theories are very confused. I believe this confusion is due to their being based on the opposite assumption of a rigid and quiescent crust. However natural such an assumption may be, it must be put aside before we can deal fairly with a theory assuming great crustal mobility.

2. Deeps and Rivers.

First, as a basis for all discussion of this movement, I must challenge the very common practice of treating the silt carried by alluvial rivers as if it were the main element in surface transfer. The lakes and seas where such rivers debouch are thick with this silt because it settles so slowly and is therefore very much in evidence. Also careful estimates show that the amount of matter so discharged is often enormous. But even so, I have to suggest that equally careful estimates of the land-slides, loose rocks, and other detritus falling down a steep declivity directly into the water would show that they give a far greater deposit of solid matter per unit area than the silt from the slow-moving water channels on an equal alluvial frontage, which settles slowly over a very wide area.

This deposit from steep declivities is partly concealed from us by its rapid settlement in the water, which is therefore generally clear, and also by the very puzzling fact that the depressions below steep declivities, so

far from being filled up by this maximum deposit, are generally much deeper than elsewhere. In fact it is a matter of common observation that the steeper and more friable the declivity the deeper will be the water at its foot, and that the most shallow water will be found near flat alluvial shores.

In so far as these statements are true they can only be explained on the principle that the greatest depressions in any locality are to be found in the areas of maximum deposit, though this is the opposite of what we should naturally expect. Before trying to consider the theoretical side of this process by which deeps may be the result of deposit, and conversely, how heights may grow higher in the face of erosion, let us see how far these two principles will serve us in explaining the salient facts of seas, lakes, and rivers.

Deeps.—The results will be most clearly seen in lakes and seas where the facts of erosion and deposit are not complicated by tidal currents. In such cases, as I have said, the greatest deeps are generally found where the shore is most steep and vulnerable, and thus allows of the maximum deposit settling directly in the water without the intervention of any alluvial plain.

The Dead Sea, which is 1300 feet below sea-level, and at its maximum 1300 feet deep, offers a good example; as it receives the whole Jordan discharge, in addition to enormous deposits from desert sandstorms, and also that coming straight down the surrounding declivities. I would regard the latter as the most important factor, since the greatest deeps are, as usual, near the steepest land.

The greatest ocean deeps near land are also always at the foot of steep coastal profiles, subject to severe weather, which must bring down very great deposit from the rocky coasts and islands. The great Tuscarora Deep, fringing the Kurile Islands and Japan, is an excellent example.

Mountain Rivers.—Current theories try to explain river action as consisting chiefly of erosion. But actually, so far as I know, the beds of rivers are nearly everywhere filled deep with deposit similar to that at the surface of the bed; and this clearly points to river-beds as being predominantly areas of deposit, and not of erosion. For if the river were eroding its bed, we should surely find the virgin rock generally scraped clear of deposit instead of being loaded with it to an indefinite depth.

We may admit that the first rough scores down a mountain-side are eroded. But as soon as these collect into hill streams they nestle down amongst the hills in a bed of deposit, due to the hill stream having a far easier gradient than its tributaries, and therefore being unable to carry forward all the material it receives from them, in addition to that which falls from the steep declivities along its own sides. Similarly the mountain river has a still easier gradient, and often still greater declivities along its sides. We may therefore regard its bed as an area of still greater deposit, and we find that it sinks the deepest valleys amongst the hills accordingly.

The only important exceptions I can see to this general rule of river deposit are in such cases as the brinks of great waterfalls, where the action is clearly erosive and results in a very high river-bed accordingly. My experience is, however, chiefly confined to young folded mountains, while great waterfalls only occur in areas of horizontal strata. In such areas I fancy the Earth's Circulation may perhaps be of a more regional and less detailed character than in the case of young folded structures, which latter I regard as the direct result of a very detailed Circulation.

In any case I have no quarrel with theories as to the "cutting back" of the heads of streams, or with the great mass of valuable work which has been puzzled out with regard to river action. All I would suggest is that, certainly in young folded mountains, and probably to some extent everywhere, a mountain stream does not "carve out" its valley by erosion, but produces a very similar effect by "sinking and shrinking" into its valley under a continuous load of deposit; while the hills on its sides are steadily raised up, at least relatively, about as fast as they are eroded.

Thus, where valleys appear to have been cut down through the crests of anticlines, I would suggest that the similar strata on either side of the river have been steadily pushed up independently, as the river sank downwards between them, and that no complete anticline ever existed. Similarly I would regard the deep-sea chalk, and other similar strata which confront one another on opposite sides of the English Channel, as having been separately raised up on either coast by the Circulation. Meanwhile the sea-bed between them has been relatively sinking under deposit, and has therefore long since pushed its chalk bed downwards to unknown depths, so that the mid-channel chalk and other strata have probably never appeared above sea-level.

Current attempts to explain mountain valleys by erosion are not only opposed to the fact that stream-beds are deep with deposit, but also have to be continually qualified by the suggestion of mysterious crustal uplifts or subsidences, which they are unable to explain. My theory would aim at a more complete explanation of the facts by attacking the problem from an opposite point of view.

Alluvial Plains.—When we come out on to the alluvial plains of great rivers we are confronted by thousands upon thousands of cubic miles of deposit, reaching down beyond our deepest borings. Yet even here current theories try to explain things as far as possible by erosion, and generally attribute the deposit to very temporary floods.

Thus a common feature of such alluvial plains, as in the case of the Tigris, is for the river channel to run through the high central parts of the plain, and to be flanked on either side by lakes or marshes which lie in much lower ground. The common explanation is that when the river floods its banks (which is only occasionally, and for short periods) the maximum deposit is dropped on the high banks near the channel, owing to the sudden decrease in velocity of the water.

It seems to me that this explanation will not bear scrutiny. One does not see any signs of the floods leaving a great deposit on the high bank, and there are mounds and other parts of the high bank which are out of reach of the floods, and so cannot have been built up by them. We can certainly explain the facts more easily by saying that the marshes are the lowest parts of the plains simply because they are the areas of maximum deposit. In any case it seems quite certain that the marshes must be the areas of maximum deposit, for two reasons:

In the first place these marshes are fed from the river by great canals, sometimes almost as big as the river itself, which carry down enormous quantities of silt throughout the year. All this silt is deposited in the lakes or marshes, as is proved by the water becoming quite clear before it reaches any outlets by which the marshes may be partly drained. This continuous deposit in the marshes must be incomparably greater than any which may be left on the high banks by occasional floods.

Secondly, we have to consider the enormous sandstorms which blow about in such countries. Whenever such sandstorms pass over water, they break its surface into waves and deposit great quantities of solid matter into it. Also, so long as the water remains, nothing is ever blown away from such areas. Now the only areas which contain water all the year round are the lower parts of the lakes, marshes, and river channels, and therefore these must be the areas of maximum deposit on account of sandstorms. While, on the other hand, the areas which are seldom or never under water, and therefore liable to the maximum erosion by wind, are the high banks and mounds near the river.

The Mississippi and many other large rivers have similar lakes and marshes on their flanks. But there are also cases, as in the Nile valley, of the lowest ground being far from the river channel, but not filled with water, and therefore not so easy to explain. They may none the less prove to be similarly areas of maximum deposit, from various causes. Otherwise these may be cases only to be fully explained by later developments of my theory which cannot be discussed yet.

Alluvial Rivers.—I also regard the river channels of such alluvial plains as normally subject to steady deposit, the deeper portions being where the deposit is greatest. The outstanding fact about such rivers is that they insist on having a grade which steadily decreases in steepness as we go downstream, so that when they flow into a steeper part of the plains they always create meanders sufficiently long to allow them to enjoy the necessary decreasing grade.

Current explanations of these facts are complicated, and to my mind unconvincing. From our new point of view we would simply say that such rivers normally carry along as much silt as the strength of their current will permit; and that the decreasing grade is necessary to ensure a current which is becoming steadily weaker, and thus to allow of the river-bed being continuously sunk under steady deposit. When the river finds

a steeper gradient, as by cutting across the neck of a meander, it suddenly removes a great load of material from its new channel, and then continues to erode its bed owing to increased velocity. On the side where this erosion is greatest the bed will begin to rise, and so drive the water to cut into the opposite bank. This cutting causes the bank to keep tumbling into the river, so that on the cutting side we have great deposit and deep water. The meander thus continues working outwards in this direction until it has become long enough to provide such a decreasing grade as will allow of normal deposit being resumed.

I am thus opposed to the general view that the deep channel in concave bends is the result of scour. I have noticed, where hill streams first debouch from the Himalayas into the alluvium, that quicksands are constantly found in these concave bends, and that one's elephant is very chary of wading near such places. Quicksands are, I think, only found in areas of deposit, and may be described as the crustal Circulation in visible operation.

The mysterious way in which strong swimmers may be sucked down by great rivers, and the rate at which such rivers are apt to swallow up anchors and cables, together with the way in which river action can be impeded by great masonry works or aprons, seem to show that quicksands are a common feature of the river-bed, and that the deposit perhaps works downwards by means of small vortices whose action is checked by wide masonry works.

However, I have only time now to present the salient features of the theory in their most uncompromising form. And however imperfect this rough sketch may be, we must remember that the current view leads to theories so complicated, and so useless for practical purposes, that high authorities will say, "You cannot legislate for the caprices of an alluvial river." This simply means that their laws are not yet known, and that there is probably something wrong in the fundamental assumptions upon which we have been working.

3. River Deltas.

The deltas of alluvial rivers require special mention because the whole theory of Circulation depends on the crust being very sensitive to changes of load, whereas the late Mr. J. Barrell, in his recent important work on "The Strength of the Earth's Crust" (American *Journal of Geology*, vols. 22 and 23, 1914 and 1915), uses deltas to show that the crust is very strong. He does this by showing the contoured plans of two deltas and the surrounding sea floors. For these two selected deltas the contours certainly look just as if the delta alluvium were superposed upon a continuous sea floor. He then simply assumes that this is the case, draws imaginary sections accordingly, and then calculates the weight of the alluvium as a proof of the enormous loads which the crust can support!

From our new point of view we would regard the greater deepness of the adjacent sea floor as due to its being an area of greater deposit than that occurring on the delta frontage; and there are good reasons for thinking that this is probably the case. However natural Mr. Barrell's assumption may be, it is thus evident that in making it he simply begs the whole question from our point of view. His view is indeed exactly similar to the old natural assumption which regarded the mountains as so much extra matter superposed upon a uniform crust. Geodesy has shown that this major assumption is certainly wrong, though I do not think it yet affords any definite evidence, one way or the other, in regard to the minor question of deltas.

This example, which is being seriously advanced as direct geologic evidence of the strength of the Earth's crust, may give us some idea of the endless unjustifiable assumptions which may be found everywhere entangled with the real facts, as soon as we begin to examine them in a new light. For instance, every geologist knows how different most geological sections might become if redrawn in the light of a new theory, even without the addition of fresh facts which that theory would probably disclose.

We hardly need new facts in the present case, as borings into delta alluvium show that it extends far below sea-level, and this seems clear evidence that the crust is not rigid, but steadily sinking under the river deposits.* However, it may be as well to supplement this by a brief explanation of the grounds on which we may expect to find greater deposit on the flanks of deltas than on their frontage.

Firstly, when the flanking shores have steep declivities the sea below them may receive much more deposit than that near the alluvial frontage of the delta, as already discussed.

Secondly, if the delta is flanked by deserts there will often be violent sandstorms blowing into the sea. These may be moving ten to fifty times as fast as the silt in a delta channel, and will have a cross-section hundreds of times as great as the total cross-sections of the little river channels on an equal frontage of delta. Such sandstorms may therefore be capable of blowing as much solid matter into the sea in a few days as an equal frontage of delta would receive in the shape of silt in a year.

Thirdly, we have the fact that silt is far more rapidly deposited in salt water than in fresh water; so that the more saline water on the flanks of a delta should cause its silt to settle more rapidly there than in the centre of its frontage where the water will generally be fresher.

These and other such causes may combine in different ways to give us

* The river channels have very little depth, and their surface must be somewhat above sea-level, so that *river* deposits cannot be laid down much below sea-level, and if they are found at great depths in a delta, they must have sunk since they were laid down. If they had been built up on a sea floor they would have the characteristics of marine deposits. The distinction should be most marked in a tideless sea.

different forms of delta. Thus I fancy that the "bird-foot" delta of the Mississippi may be due to greater salinity on the flanks of the streams causing those flanks to sink under greater deposit, so as to leave the main channels of fresher water sticking out into the sea, like fingers.

Again, some deltas, as that at the head of the Bay of Bengal, have very marked depressions cutting through the coastal platform. I regard these as due to excessive deposit. I have been told that the flood tides flowing northwards along the two sides of the Bay meet in a line above this so-called "swatch of no ground." This would give us maximum slack water over this area, and therefore maximum deposit. This conclusion is supported by the fact that the bottom consists of soft mud and ooze. My complete theory does not at all insist that an area of maximum deposit must always be deepest. But in these cases it seems to be so, and I will therefore venture to guess that, wherever such marked depressions are found in silt-encumbered seas, inquiry will show that they are areas of maximum slack water, or of maximum salinity, or in any case, for some reason, areas of maximum deposit.

These features are sometimes attributed to sunken river-beds, or to pre-historic cracks in the crust, though they are often not at all like either in shape. Also it seems to me that the surging silted waters would obliterate anything of the kind in a very short time, and that we must therefore explain their maintenance by processes which are in continuous operation at the present moment.

4. Differences of Crustal Temperature.

I will now turn to quite a different theory of the Earth's crust, which has been urged by some geologists but has not yet, so far as I know, been combined with the theory of Isostasy: namely, the idea that "Differences of elevation in the surface of the Earth are due to differences of crustal temperature." So that every elevation would be due to expansion of the crust by excess of heat.

This idea is in natural and remarkable harmony with the main principle of Isostasy. Since instead of having to explain Isostasy by rather artificial postulates as to mountains being "compensated" by deficiencies of density below them, we would simply say that the crust in high regions consists of expanded matter, and that in low regions of relatively condensed matter, the differences of expansion being chiefly due to differences of crustal temperature. It is also evident that, if this is the case, the greater heat under elevations will tend to spread by conduction in the crust, both laterally to the colder crust in the neighbourhood, and downwards towards the centre of the Earth.

I believe on general grounds that this idea, if suitably combined with others I have to suggest, would satisfy the outstanding facts of geodesy more completely than simple Isostasy has yet been able to do. But this is a question requiring mathematical investigation, and I have no time to

discuss it this evening; but will now pass on to the most important suggestion which I have to make, namely:

That the varied expansion of the crust shown by differences of elevation at its surface may be due to differences of crustal temperature and chemical changes generated by the Circulation of the Earth's crust.

This conception is the necessary and natural link between the two well-known theories under consideration, namely, the theory of Isostasy and the theory of crustal temperatures; since the crustal movements which Isostasy requires to explain its maintenance would thus become the prime cause of the isostatic condition itself, and might also afford a far more satisfactory explanation of the crustal expansion of elevations by heat than any theory which has yet been suggested.

I also believe that the fuller theory of Circulation which may be developed from this idea will be found capable of giving a more complete and detailed explanation of the salient facts of the Earth's crust than any current theory is able to attempt. The only serious difficulty arises from the question whether the Circulation can possibly be found competent to produce the required differences of temperature. I shall now try to meet this difficulty by developing the idea of a far more active and powerful Circulation than has hitherto been conceived, and will begin by stating the crustal conditions which I would associate with the theory.

5. Crustal Conditions.

We may start with a very prevalent view of the Earth's crust, by which it may be described as consisting of a solid upper crust and a plastic sub-crust. These two parts of the crust merge insensibly into one another and into the Earth's nucleus below them.

We may define the lower limit of the crust as that depth where the plastic sub-crust becomes incapable of movement owing to increase of pressure. It is considered doubtful if movement is generally possible after depths of 30 miles or so, though in my view this depth will vary greatly according to the activity of the Circulation. Beyond this depth things merge into the condition of the nucleus, which we will provisionally regard as inherently solid, cold, and inert. By this I simply mean that I am not bringing in the nucleus as a source of crustal activity, though it will be sensibly expanded by heat to very great depths at those points where the crustal temperature is highest.

Again, since we suppose depressions to consist of a colder crust than elevations, we may reasonably conclude that in depressions the solid upper crust will be thicker, and the plastic sub-crust thinner, than in the case of elevations. We would thus have a stiffer crust under oceans and seas to account for their crustal strength in resisting changes of load due to tidal movements of the sea, while still allowing ourselves more mobile conditions in higher ground to explain the great sensitiveness to load which our theory requires in such regions. I believe Milne found that

the greatest earthquakes of Japan had their seat in the bed of the Tuscarora Deep, and that the shocks became steadily milder for earthquakes seated in higher regions, until they finally faded away at the tops of the volcanoes. This would exactly agree with our views of crustal stiffness, and thus support the theory of crustal temperatures upon which they are based.

Since the undertow is the movement of this plastic sub-crust from areas of deposit to areas of denudation, this idea of its having a thicker solid crust above it in the case of depressions at once provides the possibility of greater pressure on the sub-crust under depressions, which would help to drive the undertow towards neighbouring elevations, where the upper crust will be thinner. We may, however, suppose this driving force to be considerably enhanced, as follows:

Unequal Loading, not Isostasy.—It is evident that if we have perfect Isostasy, with the same amount of matter in every vertical line from the centre of the Earth to the surface, we can only suggest differences in the vertical distribution of this matter in order to provide the differences of pressure necessary to produce movements.

Such differences in the vertical distribution of identical loads do not seem enough for my purpose. I want a more dynamic condition, with far more powerful forces available for the active Circulation of the crust. With this object I suggest that in their gradual evolution all natural depressions have become overloaded, and all natural elevations underloaded: and that this overloading at one end of the undertow, combined with the underloading at the other end, is just sufficient to overcome the intervening friction; so that any further transfer of surface load at once produces crustal movement.*

Some more suitable term than Isostasy is needed to denote this definite conception of unequal loadings up to the point of causing movement. But at present I can only suggest that my proposed title, describing the whole process as the "Circulation of the Earth's Crust," should be held to include implicitly all these new developments of the ideas included under the older term Isostasy; though actually this new title would have suited the theory well enough at any stage of its history.

6. Generation of Heat by the Circulation.

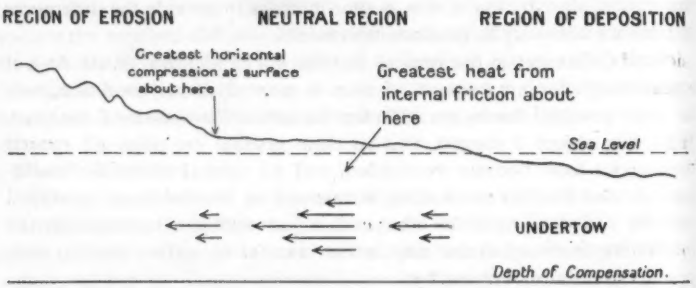
Armed with these ideas of crustal conditions and a more active and powerful Circulation than simple Isostasy could provide, we may now return to the main question as to whether the differences of crustal

* Many coral islands, which are steadily sinking under deposit, would appear to be exceptional cases of elevations which must be overloaded. Also volcanoes, just after eruption, may sometimes be more or less overloaded until erosion has relieved them again. These cases seem capable of explanation; but I do not yet see why certain quicksands, which are evidently rapidly sinking areas of deposit, should take the form of shoals, as in the case of Goodwin Sands.

temperature can be due to heat generated by the Circulation. Those who believe that differences of elevation are due to differences of crustal temperature have usually explained the latter by supposed inequalities of temperature in the nucleus. But this merely drives the mystery deeper, since these supposed differences of nucleal temperature are not connected with any known facts which would locate their greatest heat at the places where we find the greatest elevations.

Now the first thing our theory must do is to show that the maximum heat will be generated by the Circulation where we want it, namely under the greatest elevations, and that the least heat will be under the lowest depressions. This means that the maximum transfer of surface material must be located in the highest mountains, and the minimum in the central ocean deeps.

In order to show that this is the case, we may begin by considering the following diagram, which is taken from a paper by Dr. H. J. Hayford in



the American journal *Science*, Feb. 1911, and which gives a good general idea of the Circulation as it has been regarded up to the present time.

It will be seen that this diagram is based on the current conception which only considers the transport of material by rivers from distant mountains across alluvial plains to the sea. It accordingly puts the maximum surface transfer, and therefore the maximum heat generated by the undertow, not under the elevations, where we would like to see it, but midway between the mountains and the sea.

The reasoning is of course valid, so far as it goes. But, as we have already seen, my more detailed view of the Circulation would regard every river, stream, and depression as a sinking area of deposit; and from this point of view the distant transfer of material becomes a most insignificant part of the crustal activity.

I imagine that far more stuff comes tumbling down the myriad peaks and slopes of the Himalayas in a short burst of monsoon weather than the rivers can deliver into the sea in a year. In my view the greatest surface transfer of material occurs down the steepest slopes under maximum

stress of weather. And since steep slopes are most numerous, and the weather most active and effective, in mountain regions, we may fairly argue that the maximum crustal Circulation, due to surface transfer of material, will be found in mountain regions. On the other hand, it is known that in the central ocean deeps there is hardly any surface transfer through long ages, so that these will be the areas of minimum Circulation.

We have thus got our first essential in placing the greatest heat generated by the Circulation where we want it. But we must still feel it very difficult to suppose that so small a cause as the transfer of surface material can possibly produce sufficient differences of heat to account for the great differences of surface elevation. Against this feeling I would urge the following arguments:

(1) The whole theory must stand or fall on the principle that the Circulation is of the most detailed character, so that every stream and depression in the mountains will be an area of deposit, as already discussed. The highest mountains of the world are all very steep folded mountains, and the avalanches, land-slides, and other erosion down the sides of such mountains must be enormous. So that if we believe that the great bulk of this deposit is not carried forward, but sinks directly into the beds of the streams and rivers, and finally circulates back under the adjoining heights and spurs, we at once get a Circulation far more powerful and rapid than has hitherto been conceived. For its real rate of action is, by its very nature, almost entirely concealed from view, and I think its quantity may easily amount to hundreds of thousands of tons of material per annum for a single mountain valley.

(2) As we have already seen, the power available to generate heat may be still greater than this surface transfer. Since it depends on the difference between the overloading in a depression and the underloading of the neighbouring elevation, as accumulated during long ages of evolution. And pending more detailed research, we may suppose the power thus available to be very great under maximum conditions.

(3) The resultant temperature and expansion of the crust in high regions will also be due to long ages of such action. Rocks are poor conductors, so that the leakage of heat through the crust will be slow. And so long as the heat is generated ever so little faster than it is lost, we can, in time, work up to any required differences of temperature. Of course the greater such differences become the more rapid will be the loss of heat by conduction. But up to a certain point this rapid loss of heat may be easily compensated by the fact that the steeper slopes at the surface, arising from the greater differences of crustal temperature, will promote surface transfer, and therefore a more active generation of heat by the Circulation.

(4) Chemical changes may greatly reinforce the expansions and contractions due to heat. And such chemical changes may perhaps be more effective where the Circulation is most rapid, as in mountain regions.

(5) Finally, it is to be remembered that, although they seem so impressive to us, the major surface features of the globe are extremely gentle undulations, whose maximum differences of elevation from the mean surface are seldom more than the one-thousandth part of the radius of the Earth. On the other hand, the high temperatures accumulated through long ages of active Circulation, may, by conduction, extend very deep down into the nucleus. So that altogether we have a great depth through which to distribute the expansions necessary to cause the comparatively slight elevations at the surface.

The combined effect of all these considerations greatly increases the general plausibility of the hypothesis. And I hardly think it is possible to attempt much more than this at present. We first have to consider on general grounds how far the theory seems to accord with known facts. And then, before we can do any useful calculation, we shall have to re-examine many of the facts of surface erosion from a new point of view, which will probably give them quite a new complexion. Also we need to examine the theory in the light of geodesy, in order to get some idea as to how far down sensible expansion of the nucleus extends for different elevations, etc., etc.

7. Contraction and Expansion.

When I spoke just now of the central ocean deeps being areas of minimum Circulation, and therefore the lowest depressions on the face of the Earth, I am sure many will have noticed that this still left unexplained the great coastal deeps of the ocean, which, though far smaller, are often as deep as the central Pacific. These coastal deeps cannot be attributed to absence of Circulation. Indeed, I have already used them, at the beginning of the lecture, as examples of deeps due to excessive deposit. I also gave many other examples of the greatest depressions being under the areas of maximum deposit; and we will now consider how this very prevalent fact in Nature may be explained.

The current theory on the subject, which has been prevalent for at least a hundred years, is that when a deposit is laid down it acts as a blanket in preventing the radiation of heat from the crust beneath, so that the deposit will increase the crustal temperature at that point. I believe that this most plausible idea has been one of the greatest obstacles to the progress of the Circulation theory, because it really belongs to our natural conception of a more or less rigid crust.

For if we adopt a more lively idea of the Circulation of the crust, which postulates that the vertical column below the deposit is steadily sinking about as fast as the load is placed upon it, we shall find that the crust under such an area, so far from being heated up by blanketing, may really be cooled by the process. For if one pushes a cold body into a hotter layer the body itself will be heated, but the layer will be cooled, and the mean temperature of the two will be less than that of the hot

layer; and so long as we go on pushing in colder stuff, its mean temperature, and that in its vicinity, will be less than in other parts of the hot layer. Now the Earth's crust may be described as consisting of successive layers which are steadily hotter as we go down. A sinking column of this crust will therefore always have the effect of intruding colder layers amongst hotter ones, so that the mean temperature at every depth of this sinking column will be less than that of its surroundings.

Since this sinking matter will naturally be more condensed than its surroundings, owing to its lower temperature, we thus arrive at the view that the crust may be not only sinking but shrinking in areas of deposit. Conversely, we may suppose that the rising matter under an elevation would not only raise it upwards by direct pressure, but would also expand the crust beneath by the continual intrusion of hotter layers from below into the colder layers above them.

This condensation in sinking areas of deposit, and the expansion of rising elevations, may be greatly reinforced in other ways, as follows:

Firstly, chemical changes may assist the action, especially in the presence of water, which accumulates in areas of depression, while rock rising up from below may be expanded by hydration and other such processes.* It is to be remembered that, in spite of its cooling effect, the matter in a sinking column will be steadily becoming hotter, just as a rising column will itself be cooled, although heating up its surroundings.

Secondly, owing to the spherical shape of the Earth, rising matter will always be entering into a wider part of the sector in which it is confined, while sinking matter will be squeezed into a smaller compass, in so far as its particles move vertically towards the centre of the Earth.† These changes in lateral compression will also be greatly reinforced by vertical pressure, which will be constantly increasing in the case of matter which is sinking, and decreasing when matter is rising.

* 'The Evolution of Earth Structure,' by T. Mellard Reade, suggests many interesting possibilities of this kind, and includes the following footnote, which seems to indicate just the sort of theory we might combine with the Circulation theory, to their great mutual advantage:

"In a carefully thought-out treatise of much originality on 'Metamorphism of Rocks and Rock Flowage' (*Bulletin of the Geol. Soc. of America*, vol. 9, pp. 269–328; 1898), Van Hise shows in considerable detail that these mineral changes often result in increase of bulk and evolution of heat; in other cases in decrease of bulk and absorption of heat. He also points out that pressure and temperature are main factors in these mineralogical transformations. Finally, he comes to the conclusion that there exist in the earth's crust two 'physico-chemical zones,' an 'upper' and a 'lower.' 'In the upper of these the reactions take place with the expansion of volume and with the liberation of heat as end results. In the lower the reactions take place with contraction of volume and with the absorption of heat as end results. Some of the more important reactions in the upper zone are hydration, oxidation, and carbonation; some of the more important reactions in the lower zone are dehydration, sulphidation, and silication.'"

Suggestions of this kind, however, can only be properly worked out by specialists.

† For every rise or fall of 100 feet a square mile of rock must gain or lose over 250 square feet of area on this account. So that for a mile of rise or fall we get a change in area of nearly 14,000 square feet per square mile.

Thirdly, wet soil is a far better conductor of heat than dry soil, so that the loss of crustal heat by radiation at the surface may be much more rapid through the wetter crust of depressions than elsewhere.

I can do no more at present than to offer these rough hints to show how, in favourable circumstances, an active Circulation may assist deeps to become deeper and heights higher. But fortunately we are here up against physical facts. And as soon as it becomes duly recognized, for instance, that the greatest depths in a lake are generally the areas of maximum deposit, it will be clear that the Circulation theory offers the best hope of explaining the fact, and suitable specialists will soon discover how that theory requires to be reinforced in order to make the explanation complete.

8. Evidence and Examples.

Rising Areas of Erosion.—Many geologists have recognized that mountains have grown up in the face of erosion, though, in the absence of any theory to explain it, they will only accept the fact in those cases where the evidence is conclusive, as on the Himalayan frontage. We therefore find, as in the case of sinking areas of deposit, that the facts connected with rising areas of erosion have often been overlooked or misstated on account of the natural human bias in favour of a rigid crust.

Thus it is the custom to explain mountain peaks and coastal promontories by saying that they are of harder rock which has better resisted erosion. This does not show how such rocks have been brought to the surface, and is also often quite untrue, as in the case of great outcrops of so soft and friable a rock as gypsum.* And even where the rock is hard in grain, its steepness and its faulted structure in peaks and promontories are most favourable to rapid breaking down. The whole facts could therefore be better explained by saying: firstly, that where hard rocks have been brought up to the surface, this is due to their being in positions where the weather and the tides act most vigorously, as is the case with peaks and promontories; and secondly, that softer rock is raised above its surroundings by its greater liability to erosion.

I have seen so-called "stationary" sandhills in the great Indian desert, rising high out of much harder ground, though they were being blown away so fast that nothing could grow on them. Surely these can only be explained as "pockets" of looser sand, which are being raised above their surroundings because of their more rapid erosion? Similarly, current theories can afford no satisfactory explanation of the rise of offshore bars and coastal sandhills.† But this should become easy, once we can call

* The article on p. 582 of the American *Journal of Geology*, vol. **22**, 1914, shows how such cases have to be explained by rather special pleading under current theories. It also shows the great chemical expansion which may assist certain rocks when rising up in the face of erosion.

† 'Shore Processes and Shoreline Development,' by D. W. Johnson (New York, 1919), pp. 350 onwards. This valuable work quotes the highest authorities of various countries.

in wind erosion as a means of raising them after tidal erosion has brought them to the surface, with the assistance of crustal conduction of heat from higher areas in the neighbourhood.

There is plenty of very definite geologic evidence in favour of heights being due to erosion, such as the fact that Plutonic rock forms the crests of all the highest mountains in the world. But all this, like the evidence of sediments having been formed by steady sinking under a continuous load of deposit, has been discussed before now in connection with Isostasy. I need therefore only indicate how my further developments of the theory would enable previous explanations to be amplified in greater detail.

Further Illustrations.—Volcanoes are a vivid example of the Circulation of the crust in violent operation, with the undertow bursting out at the tops of the heights, where we now expect the crust to be weakest and most underloaded. Also the greatest volcanoes, like the greatest earthquakes, only occur on steep coastal profiles, where we have great transfer of surface material, and therefore an active Circulation, and where this is associated with a very stiff crust in the bed of the sea, such as would be likely to give way under deposit by means of violent and intermittent jerks. The crust of high folded mountains, on the other hand, is everywhere higher and more plastic; and therefore, in spite of its very active Circulation, not subject to such extreme shocks as the stiff sea floors at the foot of coastal profiles.

Dutton claimed that the "fan-structure," which is the typical cross-section of folded mountains, together with the overthrust faults along their frontage, are in broad agreement with the theory. But we can now go further than this, and should be able to explain the detailed complications of their structure by means of the lateral thrusts of the various undertows pressing from different directions towards the roots of every peak and spur, combined with all the upward and downward movements which we suppose to be actively at work in a region of folded mountains.

9. Conclusion.

We must, however, leave these details now, in order to consider more fully how the theory would work as a whole. To begin with, we have our main idea, that wherever the Circulation is greatest, that is wherever the action of the weather and tides is most effective, we shall have the greatest elevations and the steepest profiles.

But on the other hand, it is evident that this weather effect must always be greatly modified by leakage of heat in the crust, which will be most rapid where the differences of crustal temperature are greatest. So that although exposed to the fiercest weather a coastal elevation may be less high than a more inland one, owing to its more rapid loss of heat to the cold crust of the neighbouring ocean or sea. Conversely, the deeps resulting from deposit, or those due to absence of Circulation, will be

assisted by cold and low surroundings, since neighbouring elevations would tend to raise their crustal temperature by conduction.

By different combinations of these contrary effects of weather and crustal conduction, we can, I think, plausibly explain most of the broad facts of physical geography. For instance, the mountainous areas of the British Isles all face the weather, and the oldest rocks have been gradually brought to the surface by erosion where the tidal and weather attack has been fiercest and most prolonged. But such areas are often not the highest because of their loss of crustal heat to the neighbouring oceans and seas. Thus Cornwall, with deep seas on either side, and the west of Ireland, with a still deeper ocean before it, cannot attain to such elevations as Wales, which, while also well exposed to the weather, is situated amongst higher and therefore crustally warmer surroundings.

Again, if we consider the violent attack of the monsoon weather on the southern frontage of the Himalayas, we shall find that frontage steadily raising up its foothills range by range out of its "foredeep," in face of that weather. This may be roughly explained as due to the conduction of crustal heat from the higher mountains aiding the foothills to rise in the face of erosion. Meanwhile we find the great spurs, carrying the loftiest peaks, all face the weather, so that their growth must have gradually protected the watershed behind them from weather attack. The crustal Circulation of this watershed has thus been steadily diminished, and it is therefore no longer able to maintain a great crustal heat in the face of losses by conduction. It thus steadily loses height, and subsides into the condition of the lower Tibetan plateau behind it. And we may further suppose that the great spurs will gradually pass through similar changes in their turn, as they become more and more protected by the rising of their frontage. We thus have the idea of a rising and advancing frontage, followed by a subsiding area behind the highest array of peaks.*

So far as it goes I think this is in general agreement with the facts, and in any case it will serve the purpose of showing how we may explain the gradual advance of any given set of surface features from one region to another. And as changes in these features will in turn modify the weather, it is clear that the complete theory might be made to explain the gradual transformation of both the weather and surface conditions in any given area.

Crustal Mobility.—This is about as far as I can carry these speculations at present; and I feel that their greatest difficulties may arise from the current habits of geological thought, since we cannot easily get rid of the ideas that deposits cause "blanketing," that elevations tend to get worn down into "peneplains" by "cycles of erosion," that streams are "rejuvenated" after wide intervals of time, and so forth. Now these are

* I do not know whether any great advance of the main axis has certainly taken place in this particular case. But it seems certain that the frontage has advanced in face of the weather, by raising up successive foothills from the alluvial plains.

not facts, but rival theories, largely due to our crude natural bias in favour of an inert and rigid crust. So they should not be allowed to embarrass a theory based on the opposite assumption of extreme crustal mobility. But in practice it will be hard to prevent this, since all the facts have been examined and collated in the light of these "intermittently-rigid" theories. From my point of view, even the relics of this natural bias may prove as great a source of confusion in geology as the natural human feeling that the sun goes round the Earth used to be in the case of astronomy.

However, the great point is that the ideas I have sketched out do offer the prospect of a complete theory providing incessant crustal activity of the most detailed character. The evidence in favour of such activity is overwhelming. So that once a theory can be found to explain it, we may hope that it will not be too long before we can all accept, in their fullest sense, the great lines from Tennyson's "In Memoriam," which have been so often quoted by eminent geologists:

"There flows the deep where grew the tree.
O Earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mists, the solid lands,
Like clouds they shape themselves and go."

Before the paper the PRESIDENT said: Colonel Tandy is an officer of the Survey of India who has for some time made a special study of the subject about which he will address us this afternoon. I invite him to give us his address.

Colonel Tandy then read the paper printed above, and a discussion followed.

Colonel Sir GERALD LENOX-CONYNGHAM: Colonel Tandy's very attractive theory gives one so much food for thought that he must not complain if his audience suffers slightly from sensations of mental indigestion. It seems to me that the path to the acceptance of this theory is strewn with serious difficulties, and I think, however attractive the theory as a whole may be, it is one's business to point out those difficulties which occur on hearing the lecture read.

I find great difficulty in thinking that there is a very detailed response to the relief of load by erosion and the overloading of areas of deposition. Mr. Hayford in his investigation of Isostasy found that isostatic compensation is probably complete at a depth of 70 miles. He did not, as far as I am aware, make any estimate of the depth at which the compensation might begin to take place—that is to say, at which the undertow would commence. But the sort of idea is that this is not likely to begin at a less depth than 30 or 40 miles, and if I am not mistaken, seismologists demand a rigid Earth to a greater depth than that—I speak under correction. If that is the sort of depth at which the undertow can begin, I find it difficult to believe that the bed of a mountain stream into which deposit is being poured from the hillsides can sink downwards and cause the hill alongside it to rise upwards. Different mountain streams which are cutting through the hills are separated by no great distances, so that this

conception demands an extremely detailed response in the action of the undertow. Also, at any moment in the life of a mountain stream it seems to me that the load on its bed must be something less than it had been when its bed had cut less deeply into the valley. There must be less load on it than before, so that I do not see where the weight which could depress is to be found.

Colonel Tandy spoke of deltas and of Mr. Barrell's argument that a delta showed that the crust had great strength. He mentioned that borings showed that alluvial matter extended well below sea-level. I am not familiar with the literature on this subject, and I do not know whether borings show that the alluvial matter extends below the floor of the adjoining ocean. If it only goes below sea-level I do not think the argument that alluvial matter has sunk down is convincing. If the matter goes down deeper than the floor of the adjoining ocean then I think that is an important and good argument.

Colonel Tandy postulates a state of things in which there is a good deal of overload on areas of deposition and underload in areas of erosion, so that a small extra load taken off the one side and placed on the other will cause the undertow to begin to act. Now the evidence that isostatic equilibrium really exists is pretty strong, and this state, of there being overload and underload, seems to me inconsistent with it. I think that is a difficulty which we would have to meet. I do not feel competent to go into the question of whether transference of matter by erosion gives sufficient power to cause hills to be raised up. I take it that the transference of matter is the primary force which Colonel Tandy has in view to produce the motive power which builds up mountains, and I think the amount of power available should be calculable. I think observation should be able to give us a good estimate of what power is available. The amount of erosion might be measured, and approximately the distance to which it has been carried vertically and these would give the force available for mountain building.

I also find great difficulty in understanding how the fact of depositing matter on an area should press it down to a lower level than that which it originally had. If there is isostatic equilibrium and you then place an additional load on an area it should certainly sink downwards, but the matter deposited will be almost certainly less dense than the matter deeper down in the column, and therefore a sinking amounting to less than the depth of the deposit should suffice to restore the equilibrium.

Dr. J. W. EVANS: We ought to be very grateful to Colonel Tandy for his boldness in placing before us his novel ideas. He reminds one of brilliant debaters like Chesterton and Shaw who bring forward social theories which are exactly the contrary to what we always supposed to be true—and make out a remarkably good case! In the same way, I think Colonel Tandy has made out a case which has a great deal to be said for it, but if he won't mind my saying so, I believe there is as deep a paradox in his explanations and arguments as those that often lie behind the expositions of Chesterton and Shaw. I am at one with him in the importance that he attaches to the phenomenon of Isostasy—to the idea that where the balance of the crust of the Earth is disturbed by one reason or another, it tends to adjust itself like the surface of water—or still better, the surface of a bowl of treacle. Isostasy is merely a tendency to the restoration of equilibrium. This is never perfectly achieved. It is an ideal to which the Earth's crust is always tending. Just as "Man never is but always to be blest," the Earth's crust never is but always to be ultimately made isostatic.

Equilibrium is disturbed not only by the transference of material from the

mountain tops to the ocean deeps or the plains, but also by movements in the Earth's crust. Where there is compression there is the Earth folding. In some cases the Earth's crust is forced upwards. If the masses which are forced upwards are large enough, sooner or later the weakness of the Earth's crust allows them to sink again and lose the elevation which has been imparted to them by compression. Elsewhere the crust is forced down. That also tends ultimately to be corrected. In other places, a complex aggregate of corrugations results, which constitutes an extra weight that disturbs the equilibrium. But it slowly sinks down till equilibrium is restored. But there is another way in which the equilibrium may be disturbed. In some places the Earth's crust has a tendency to gape. Instead of compression there is tension and one portion moves away from the other. If such a gap is wholly or partially filled from the heavy magma below, the isostatic balance is again disturbed.

As soon as equilibrium is disturbed there is a tendency to restore the balance. This tendency takes time to develop, and the time required depends upon the relation of the forces which are generated by the want of equilibrium to the strength of the materials of the crust. If the force is very small an isostatic balance will never be obtained. Suppose a block of granite 10 feet each way were placed on a sandstone or granite plain. A thousand million years would not suffice to cause it to disappear by isostatic action. The want of equilibrium must be on a sufficiently large scale for the forces developed to be larger than the strength of the materials involved, and that constitutes a very serious objection to one portion of Colonel Tandy's theory; for he believes isostatic adjustments to take place in comparatively small areas. But it is the results that he supposes to ensue from these movements which are the most difficult to understand. He wishes us to believe if you have a large amount of material taken from the mountain top and accumulated in the adjoining valley, that this causes a deepening of the valley and an underflow towards the mountain, and that the friction of this flow generates sufficient heat to raise the mountain still higher. That seems to me a most extraordinary case of perpetual motion. The energy of position of the materials descending the mountain side is converted into energy of motion, and that is converted into heat when the motion is arrested and this heat is mostly radiated into space. At the same time the weight of the fallen material is supposed to cause the valley bottom to sink, and this to give rise to a slow underground movement towards the mountain. All the energy of that motion must be derived from a small fraction of the original energy of the descent down the mountain side and yet this is supposed to generate, by means of friction, sufficient heat to raise the mountain higher than before!

Colonel Tandy has attacked the theory of the blanketing, first enunciated I believe by Dana, who showed that an accumulation of material on the sea bottom may act as a sort of blanket to the rocks below. As heat is always coming from the Earth, the rocks below these accumulations will become heated, and the increase of heat may be so great that hard resistant rocks may become softer and unable to resist the compression of the Earth's crust. At the same time the accumulated weight will tend to force that particular point downwards. The result of compression in a region of accumulation is therefore to produce a downward bend of the ocean floor. This is the cause of the strip of deep water which is so frequently found in great oceans in the neighbourhood of continents.

Colonel Tandy's paper is so full of original ideas, so full of statements

which one would like to contest, that I could have said much more if time had permitted. As it is I will conclude by expressing my opinion that it is all to the good that we should have such papers brought before us. We are too apt to think that certain fundamental propositions are firmly established for ever. We should always be critical of the conclusions which have been arrived at, and should welcome an *advocatus diaboli* like Colonel Tandy who comes and ells us that we are all wrong, though he may not succeed in convincing us that this is the case.

Mr. A. R. HINKS: I have seen a good deal of this paper, and although I am not in the least competent to discuss the geological points which are put forward by Colonel Tandy, I should like to make one or two remarks about the attacks that have been made upon him in the discussion. Sir Gerald Lenox-Conyngham has brought forward Hayford's depth of isostasy at 70 miles or so, as if in his opinion it in any way controverted Colonel Tandy's views. I should like to demur to that idea on two grounds, first of all that Hayford never considered isostasy in any detail at all but as a broad principle; and secondly, that I have always felt his numerical conclusions were singularly badly based. Therefore, on two grounds I should demur to using Hayford as a name to throw at Colonel Tandy. And as to what Dr. Evans has said, I should like to make two or three observations. Colonel Tandy has been called bad names like Bernard Shaw and *advocatus diaboli*: I wondered myself they did not call him De Morgan, who wrote a very celebrated and interesting book: 'A Budget of Paradoxes.' That, however, is by the way. Dr. Evans said, with perfect conviction, that if you had a cube of granite 10 feet a side and set it out on the level ground it would not sink by means of isostasy. I should like to ask Dr. Evans how he knows that? It would, I believe, be perfectly possible to have said with equal confidence before Kelvin did a celebrated experiment in his laboratory, that suppose you took a jar of water and you put in it halfway up a layer of pitch about 1½ inches thick, and that underneath the pitch you had a small fragment of cork, and above the pitch a small fragment of heavy wood, those things would stay there for ever—that the very small forces acting upon the pitch would not have been enough to carry the cork up and the wood down. But in the course of six months or so the piece of cork below appeared at the top and the wood below. There is also one other point on the extraordinary case of perpetual motion, about which Dr. Evans made some discreet fun. I do not think he did justice to Colonel Tandy in that, because if a geologist is prepared to admit that the mountains have risen rather recently (some of the very highest), there must be energy available to produce that rising, and I do not see why Colonel Tandy is not to be allowed to appropriate some of that energy which is freely used by other geologists, and why he should be expected to provide the whole of this energy for the process he advocates by the stuff falling down the mountain side. I think he is at liberty to draw upon that source of energy like any other geologist.

Lieut.-Col. TANDY: I must thank Mr. Hinks for his kind support, but at present I do not want to reinforce my theory by imaginary forces emanating from the interior of the Earth. We should, I think, first try to exhaust the possibilities of the forces acting on the surface about which something definite can be known. And since these forces are capable of controlling the tremendous movements of the solar system and causing the circulation of the oceans and the air, I do not see why they should not be found equally capable of causing the incessant circulation of the Earth's crust. It must be remembered that

though I suppose mountains to be raised up by this means, this will always be balanced by corresponding subsidences elsewhere. As regards Dr. Evans's block of granite, I only claim that it would sink if it formed part of the débris in a natural depression, which I suppose to be an already overloaded and sinking area. I also think that the circulation in high mountain regions takes place only a very few miles below the surface.

I will, however, readily admit that the details of my theory cannot pretend to be at all perfect or complete in their present initial stage. For instance, Sir Gerald Lenox-Conyngham expressed his difficulty in believing that deposits may make a depression deeper or that heights may become higher by reason of erosion. I can at present do no more to make the idea plausible than is indicated in section 7 of my lecture. I think the mere challenging of the long-established idea of "blanketing" is a big step forward, and that the section does at least indicate the possibility of a full and complete explanation being attainable.

I should like to deal further with many of the difficulties that have been raised, but I think it is more important to urge that imperfections in the details of my theory are really minor issues at the present moment. The important questions are whether heights do actually grow in the face of erosion, and whether the greatest deeps on coasts and rivers do correspond with the areas of maximum deposit, and generally whether my theory is capable of giving a coherent explanation of the facts. In a matter of this magnitude the main idea must first be sketched out before the necessary variety of specialists can combine to work out the details of a perfect theory. The idea that the sun was at the centre of the solar system had to wait generations before it could be properly explained by the laws of gravity; and in the meanwhile it had to win its way to acceptance on the bare grounds that it was the only coherent explanation of all the facts. I therefore feel that all theoretical difficulties will be set right in due course if only my main idea is found capable of explaining the facts of physical geography in detail. For if it can do that it can do more than any current theory is able to attempt. So that all geologists will gradually begin to use it for their field work, just as they are now using principles based on an indeterminate mixture of theories far more imperfect and incoherent than mine.

I therefore urge that my theory should first be judged by its practical power of explaining the facts. Up to the present moment I am the only person who has had any real chance of seriously testing it in this respect, and I wish I had time to give you many more examples of its agreement with the main facts of the Earth's surface. However, I have challenged many facts this evening, some of which can be tested without much difficulty; and for the rest I can only say that the more I have tested the theory against a great variety of facts the more convinced have I become of its ultimate power to explain them all. I therefore venture to prophesy that those geologists and specialists who are the first to improve the theory and apply it to their own line of work, will find themselves the pioneers of the New Geology of the twentieth century.

For myself I can only pose as the explorer who has lighted by a happy chance on this new and untried way through the mazes of physical geography, and who is now trying to indicate its possibilities which he alone has seen. I cannot pretend to be an expert in regard to the more recondite points of geology, chemistry, and physics, which enter into this problem. But whatever the imperfections of my attempt may be, I do feel that I am at least pointing in the right direction. And now, having done that to the best of my ability,

I can await the issue with confidence, feeling sure, as I do, that in due course the right men will rise up to throw the light of their wider knowledge in a direction which I can only indicate very imperfectly at present.

The PRESIDENT: We have had a valuable discussion on a subject which must keenly interests all geographers—especially those of us who have spent much time among mountains. We cannot yet arrive at any definite conclusions. But we feel we are on the track of something which will have an important bearing on Geography. On your behalf I cordially thank Colonel Tandy for having brought the subject forward again and made so valuable a contribution towards our understanding of the principle of isostasy.

GEOGRAPHY AS A PIVOTAL SUBJECT IN EDUCATION

Sir Halford Mackinder, M.P.

Read at a Meeting held in the Map-room of the Society on Friday, 18 March 1921.

I HAVE come here to-day as Chairman of the Council of the Geographical Association, the dutiful daughter of this great Society, to ask for your maternal help at a critical juncture in the movement for the wider and better teaching of Geography. The Geographical Association has some 4000 members, nearly all of whom are teachers of Geography. I speak therefore not only from a personal experience of more than thirty years, but also as the representative of an organized branch of the teaching profession.

The main point to which I am going to direct your attention is that, whereas there is now a full recognition of Geography by Educational Authorities as regards both pupils under 14 and students over 18, yet Geographical teaching in the four adolescent years between 14 and 18 is starved both in respect of time and of money. In order that you may appreciate the position, it is necessary that I should trace very shortly the progress of the movement for the better teaching of Geography from its small beginning to a widespread promise. Then I will state the view of the Council of the Geographical Association that in the present condition of educational affairs it is in the power of the Board of Education by sympathetic or unsympathetic administration to reap or to blight the harvest of a generation of effort. I will conclude by expressing my view that Geography is now ripe to be a pivotal subject in coherent schemes of secondary education.

If there be an occasional autobiographical note in what I am going to say I hope you will forgive me, for I must refer to some matters *quorum pars fui*. In fact, I shall frankly draw on my reminiscences rather than attempt a detached and formal record. It was for a geographical adventure that I was commissioned by this Society just a generation ago,

and I am going to tell you an explorer's tale. I have no doubt that the experience of others here present has been parallel. *Ex uno disce omnes.*

As has been the case with other successful careers, our movement made, in the first instance, a false start down what proved to be a blind way. For a number of years in the middle of last century the Royal Geographical Society offered medals annually for competition among the boys of a few of the greater public schools, with the result that two or three boys were each year specially coached by one or two enthusiasts among the masters—notably Mr. Robinson of Dulwich—and nothing more was accomplished. It is interesting, however, to observe that with a sound instinct, as I think, the aim of those days was directed precisely to the later school years. But the entrenchments of the established curricula were impregnable to a frontal attack, and fortunately so, in my opinion, for neither the subject of Geography nor its teachers were then prepared for a principal *rôle* in education.

In the early eighties the Council of this Society began to realize that they were missing their mark, and, under the lead of Mr. Francis Galton and Mr. Douglas Freshfield, they decided to withdraw the offer of the medals and to embark on a better calculated effort. Mr., now Sir John, Keltie was despatched to the continent on a reconnoitring mission, and returned with an eye-opening report and a collection of maps and apparatus gathered from several countries, but principally from the German-speaking lands. The lead of Germany in Atlas cartography and in scientific and philosophical Geography was at that time indisputable and due probably to the military influence in German education. From the days of Humboldt and Karl Ritter there had been professors of Geography in most German universities. In this country, on the other hand, the geologists had captured Physical Geography, and had laid it out as a garden for themselves, while the remnant known as "General Geography" was a no man's land, encumbered with weeds and dry bones. Before British Geography could come into its own again it was necessary to reannex the garden and to clear and cultivate the waste. The universities were obviously the proper agencies for this endeavour.

Mr. Keltie's Exhibition of continental efficiency in the way of maps and apparatus, advertised in the newspapers, attracted my attention, for I had been caned at school for drawing maps instead of writing Latin prose. I came up to London to see it, and though he did not know his young interrogant I had the honour of asking some questions of Mr. Keltie himself. Having just graduated, I naturally proceeded to draw up a set of lectures for the Oxford University Extension, and I gave them the title of "The New Geography." After all, one of the best ways of learning a subject is to set to work to teach it! The result was that I was sent for by Mr. Bates, then the veteran secretary of this Society, and was told to write a paper on "The Scope and Methods of Geography."

Though that paper contained nothing which would surprise any of us to-day, it divided the Council of this Society into contending and indeed rather angry parties, and the discussion of it occupied two successive evening meetings—there were no afternoon meetings in those days. In that summer, 1887, the Society agreed with the Universities of Oxford and Cambridge to subsidize University Readerships in Geography, and I was appointed to Oxford—the second Reader in Geography to lecture there, the first having been the famous Elizabethan Hakluyt. At my opening lecture there was an attendance of three, one being a Don, who told me that he knew the Geography of Switzerland because he had just read Baedeker through from cover to cover, and the other two being ladies who brought their knitting, which was not usual at lectures at that time.

Curiously, the first effect of the new start was felt in the elementary schools. Growth is slow to begin in a university, and as my stipend was not very large, I threw myself into Extension Lecturing, and in three years travelled 30,000 miles and taught several thousand pupils, many of them elementary teachers and students in training colleges. We studied chiefly what Huxley had called Physiography, for the great majority of the students were not grounded either in history or natural science, and were therefore not prepared for Geography proper.

After a year or two, as the result of an alliance with the Faculty of History, my Oxford classroom began to fill with students of Historical Geography, but Physical Geography still met with a chilling reception. Two facts had become clear: first, that the organization of our universities into faculties of natural science and humane letters rendered it very difficult to enlist students for a hybrid study, half physical and half humane; and secondly, that no teaching of Geography really worthy of a university would be practicable until boys came up from school with a better grounding in the necessary rudiments. The policy indicated, therefore, was to concentrate on training a few post-graduate students who should go forth into the schools and prepare pupils to enter the universities with the geographical mode of thinking already established. With this in mind, I seized the chance of a British Association Address in 1895 to plead for the establishment of a University Institute of Geography, in which should be assembled both the physical and the philosophical teaching of the subject. My dream was realized in 1899 in the Oxford School of Geography. The University agreed to grant a Diploma to whole-time students of the school, and I was so fortunate as to obtain the late Dr. Herbertson as my principal assistant—I made an express journey to Edinburgh in order to dissuade him from accepting an American offer which had been made to him, and I took him back with me to Oxford in triumph.

About this time a step had been taken the significance of which was not at first recognized. Mr. Dickinson of Rugby had been using lantern

slides in his classroom, and wanted to organize a system of exchanging slides between school and school. The Royal Geographical Society referred him to me, and at my invitation the first meeting of the Geographical Association was held at Christ Church, Oxford. Herbertson soon became Secretary of the Association, which under his auspices flourished, and began to publish a journal, the *Geographical Teacher*.

Meanwhile the subject itself was being reshaped. Suess's 'Das Antlitz der Erde' gave a geographical turn to that department of Geology which is now known as Geomorphology. So revolutionary were his method and outlook that the Royal Society hesitated for years before awarding him a medal. Bartholomew's Meteorological Atlas, edited by Buchan, gave us in modern form the necessary apparatus for a corresponding geographical trend in what I will describe as Geophysiology. Davis in America clothed the accumulating analysis of river systems with a terminology often laughed at but none the less provocative of fruitful and systematic study. The conception of the distribution of plant and animal associations and not merely of species completed the sequence of ideas needed for a regional, that is to say a truly geographical synthesis. I believe that I was the first habitually to use the expression "regional" in this connection, but Herbertson made a further advance with it in his paper on the "Major Natural Regions of the World." If the Philosophical or Humane study of Geography lagged behind for a time that was no more than was to be expected, for that study postulates not only developed Regional Geography on the physical side, but also the application of economic and strategical ideas to the past and present distribution of human societies. Here the work of the French geographers and sociologists has been important, and notably in their different ways that of Vidal de la Blache and of Leplay. Not the least incentive to a scholarly geography in the completest sense has been the need of it as a weapon of research for the reconstruction of the early history of mankind as revealed by excavation. Perhaps without being invidious I may name my friend Prof. J. L. Myres as a pioneer in the application of Geography to this purpose. When we remember that the whole of this great academic superstructure is based on an infinite labour of surveying in the field, and that it is only within the present century that we have so far reduced the unknown areas on the globe that we can begin to generalize with a sense of completeness, we obtain some measure of the advance achieved in the last thirty years.

The results of all this work—organization, teaching, research, and writing—ripened suddenly to a harvest in the ten years before the war. Professorships and Lectureships in Geography were established in nearly all the universities of the kingdom. Competitors to the Oxford School appeared in several quarters. A place was found for Geography in Pass Degrees, and presently in Honours Degrees. Students began to flock to the classes, and no difficulty was experienced in placing the better of them

in posts, usually of course as school teachers. Text-books appeared in increasing number. A few even of the great public schools began to make Geography the specialty of one of their masters.

This was the position when the war came upon us, and then in a rudimentary sort of way the whole people began to think strategically, or in other words geographically. We who were growing old in the cause thought that when the war was over our favourite study would be permanently established in its rightful place. But as with other sanguine war hopes and forecasts the realization, although not contrary to what was expected, has not been complete. True that the classes have never been so crowded with students as at present, and the Geographical Association has never had so many members. Further victories, too, have been won in the curricula for University degrees. During 1920 there were at least ten Summer Schools in Geography in England and Wales, most of them overcrowded with students. But there is none the less a feeling of uncertainty prevalent among teachers of Geography, a feeling that the promise of a rich harvest may after all be disappointed, and a spirit, therefore, of discontent with our Educational Providence.

In plain words, it is felt that the secondary schools are the key to the position, that the curricula of those schools are passing more and more under the control of the Board of Education, that the Board in its Secondary Branch is not very sympathetic with the claims of Geography, and that it is in the power of the Board to stop advance just at the time when as the result of a whole generation of endeavour Geography and geographers have been shaped to the purpose of an efficient educational weapon. Let there be no mistake about it, if the upper classes in secondary schools are not allowed, in cases where it is so desired, to make Geography a main subject of instruction, then the University study of Geography will be impoverished for the reason that it will be impossible to exact a preliminary knowledge of students entering the classes, and still more for the reason that no adequate scope will be offered for those who graduate in the subject. Once let it be clear that that vicious circle is to be established and it will inevitably follow that the effort to improve the standard of University Geography will be relaxed, and in the long run even the elementary schools will feel the effect.

The issue of regulations discouraging to geographers began before the war. It is quite likely that there was no intention to discourage, but we have to deal with the effect. In 1913 the Board of Education (Secondary Branch) issued a Circular (No. 826), still not withdrawn, in which it was stated that "It is not necessary that separate instruction in both History and Geography should be given in all forms. In schools in which the pressure on the time-table renders it necessary, a shortened course of geography, terminating at the age of 14 or 15, may be accepted." As a matter of fact this recommendation had at first very little effect. The movement to improve Geography teaching continued in spite of it, and

more and more schools and pupils studied the subject, while the work done was increasingly valuable.

In 1917 the Board of Education (Secondary Branch) decided to encourage work in schools beyond the age of 16 (matriculation standard) by initiating what are known as "Advanced Courses" for pupils between 16 and 18. With the principle every one interested in education will agree, but unfortunately some details of the scheme as drafted have proved disastrous to Geography. It is the one and only main subject of a liberal school education, which it is impossible to take as a main subject in any of the Board's advanced courses. The consequence is that much official pressure is exercised to prevent pupils from making Geography a principal subject between 16 and 18, and the courses are too full to allow of its being taken at all adequately as an extra.

Two results follow from this. In the first place, schools naturally encourage pupils between 14 and 16 to concentrate upon subjects which will be important for them between 16 and 18, and Geography is suffering from this in a large number of schools. Time-tables are being readjusted against Geography even in schools with really distinguished teachers of the subject. This is now reinforcing the evil influence of Circular 826 quoted above.

In the second place, both by the regulations and by the early dropping of Geography, it is suggested that the subject is not of an importance comparable with that of other subjects of the curriculum, and that it can consequently be taught by teachers of a lower grade. Discrimination in detail, as regards status and salary, against teachers of geography, however qualified, is becoming widespread and dangerous.

And this is not the worst. As a result of the antagonism to Geography above noticed the subject has great difficulty in claiming any place in the "Second Public Examinations," and those universities which have recognized it here have need to act virtually in opposition to the Board's schemes as drafted by its Secondary Branch. In the case of some universities, there is undoubted feeling at what is considered the grave indifference of the Board to an essential part of the training of citizens. The case is made more serious now that Government scholarships and scholarships given by university authorities and local authorities as well, are to be awarded in ever-increasing proportion on the result of the "Second Public Examination."

The action of the Board is thus producing a situation in which Geography is to be taught up to the age of 14, but as little as possible to pupils from 14 to 18. The universities clearly wish it to be taught to students over 18, and thus have to deplore the reactionary attitude of the Board's Secondary Branch. The great point is to secure some recognition of Geography as a subject in the "Advanced Courses."

The Board did recognize, experimentally, courses including Geography at Leytonstone and at Ruabon. These courses were allowed grants on

the basis of "grants for experiments," *i.e.* £250 per annum against £400 for advanced courses. I understand that Ruabon School has now set this experiment aside and organized an advanced course with Geography in a subordinate position so as to get the £400.

The central idea of these "advanced courses" is the coherency of the subjects chosen, so that they shall form a group of such a nature as to be educationally complete. Every one will agree with this intention. What I wish to submit in conclusion is that if liberally interpreted this very idea should work out in favour of Geography and not against it. Geography is inherently not an elementary but an advanced subject. It postulates both scientific and humane knowledge. No one can appreciate geographical correlations without some mathematical, some physical, some economic, and some historical knowledge. Geography is essentially a mode of thought which has its scientific, artistic, and philosophical aspects. If our aim is to give unity to the outlook of our pupils, and to stop that pigeon-holing of subjects in their minds which has prevailed in the past, then Geography is admirably fitted as a correlating medium. It may very easily be made the pivot on which the other subjects may hang, and hang together.

Let me indicate my meaning by two or three examples. I can conceive of a very fine course for boys between 16 and 18 conducted by three masters working in harmony and teaching three major subjects, such, for instance, as Mathematics, Geography, and Greek, and two minor subjects, say, Physics and Latin. The geographical teacher would be able to assume the mathematical knowledge needed for map projections, the physical knowledge needed for the understanding of the air and water circulations, and the historical knowledge which accompanies the modern teaching in Greek and Latin. He would no doubt choose the Mediterranean for his special subject, and would fascinate his students by linking together all their studies in a concrete philosophy. To take only one other illustration, let us assume a similar combination, but with the following components—as major subjects, Chemistry, Geography, and French, and as minor subjects, Botany and Spanish. This would be a commercial course, and the geographer would be able to postulate the chemical and botanic knowledge which lie at the root of economic geography, and on the other hand such a knowledge of the Romance lands as would enable him to take Western Europe and South America for his special regions of study.

No doubt it will be urged that History better than Geography would form the pivot between the precision of science and mathematics on the one hand and the human faculties of imagination and expression on the other hand. I desire to make this point in that connection. It is obvious that neither of the outlook subjects—History which looks back through time and Geography which looks out into space—can be studied wholly apart from the other. The question before us, however, is whether our

educational perspective shall be based on History with some Geography or on Geography with some History. Now if I were asked why those who have received a university education are so frequently excelled in practical life by those whose main schooling has been won in the world, I should say that it is in no small degree owing to the sterilizing tendency of too strong a historical sense in their mental equipment. Far be it from me to depreciate the statesmanship which is based on the sense of the continuity of events in time. But what matters to the vast majority of people, who must consider to-day and to-morrow rather than yesterday, is the outcome of history as expressed in the facts of to-day, and not the process by which that outcome has been effected. Nothing is more noticeable in the present working-class demand for education, as illustrated for instance by the Workers' Educational League, than the call for economic, legal, constitutional, and geographical information. If the educated classes are not to lose their grip and their influence over the half-educated proletariat, they must strive for a sense of "actuality" in the French meaning of that word. In other words, Mahommed must be thought of as embodied in the still greater fact of Islam in the world of to-day and not merely as a romantic figure of the past. So with Buddha, and Augustus, and Charlemagne, and William the Conqueror, and Shakespeare. Now Geography in its full scope not only deals with the physical environment of human societies but also with those societies themselves, for they are geographical facts. This is the principle which I have ventured to describe as "momentum" in Geography. Geographical analysis alone is not enough to explain the greatness of many centres of urban life. You must include "compound interest" on the original geographical "capital." You may analyze the position of London, and show that it was founded on a defensible hill with a water supply in its gravel top and tidal creeks for boat-harbours, but you have only so explained a big village on the site. The financiers and merchants of the world resort to London to-day, not because of these physical advantages in the little clay plateau beside the Thames bank, but because eight million people dwell here, and there is established among them the market with the greatest "good will" in the world. In other words, however fascinating it may be to investigate the beginnings of London, we must recognize that the little streams, hills, woods, and marshes, which before the houses were built shaped the site of the city, have very little actually to do with the persistence of the London money market and entrepôt trade. It is in short an independent geographical fact that you have beside the Thames in these days a "stratum" of human beings comparable with a stratum of coal or of soil; a "deposit" of human energy, skill, and habit of working together, which it would be impossible to move to a distance without destroying. Thus the results of history are embodied in geographical facts in a manner quite analogous to the determination of the physical geography of a country by its geology. Everything depends upon the

point of view. As I said in 1887, in my paper on the "Scope and Methods of Geography," the distribution between Geography and Geology lies in this, that the geologist looks at the present in order that he may interpret the past, whereas the geographer looks at the past in order that he may interpret the present. We shall make an equally clear working distinction if we say that the historian uses Geography in order to interpret the past, whereas the geographer uses History in order to interpret the present. And I believe that the geographer's standpoint is vitally important to-day.

I have only one more thing to say. Do not let it be supposed that we geographers are asking for a "soft option" in the curricula of secondary education. By all means let there be the most stringent requirements in regard both to the qualification of the teachers and in the exaction of mental effort from the pupils. All that we are demanding at the present time is that when these conditions are satisfied the pupils and the schools which select Geography as a principal subject of education shall be under no penalty either financial or in the examinations.

REVIEWS

EUROPE

The Influence of Man on Animal Life in Scotland: a Study in Faunal Evolution.— **James Ritchie, M.A., D.Sc., F.R.S.E.** Cambridge: The University Press. 1920. *Maps and Illustrations.* 28*s. net.*

SCOTLAND, as a region isolated and uninhabited (so far as any evidence to the contrary exists) till after the close of the Great Ice Age; whose earliest human inhabitants arrived at a period more or less certainly determined; and whose flora and fauna have been acquired since the country was left a *tabula rasa*, has been chosen by Dr. Ritchie—who by birth, education, and his responsible position in the National Museum in Edinburgh is specially qualified for the task—as a suitable region for an intensive study of the evolution of its present fauna and flora as influenced by man's interference during the centuries he has since occupied the country.

Inasmuch as Geography includes in its survey the Earth and all that therein is, this volume may be acknowledged as a contribution, in a general way, to the science with which this Society is chiefly concerned, but its subject deals more intimately with biological problems.

Dr. Ritchie contends that its earliest human occupants invaded Scotland in the Azilian or Early Neolithic period of civilization, when the 50-foot Raised Beach (which is now part of the Carse of Stirling—a wide and fertile plain many square miles in extent) was the limit of high water. On the ridge of this raised beach, the author believes, occur his earliest relics, as kitchen middens, to which were carried the shell-fish he collected at low tide to feast upon. At the close of the Palæolithic Age Scotland, till then ice-clad and devoid of life, derived its inhabitants from the continent across the North Sea, then dry land. To these Azilians the main "inland marks of the country must have appeared almost as they are to-day"; but Scotland otherwise was a country of

swamps, low forests, fertile meadows, and snow-capped mountains, whose estuaries penetrated further inland than now; while on its plains and in its woods roamed many creatures which are strange to its present fauna. Man was not long in beginning "intentionally and unintentionally, directly and indirectly, to transform and supplant both the animal and vegetable life," through his domestication of many species of the indigenous wild mammals and various kinds of birds; through his protection of other species to supply his needs, to promote sport, or for æsthetic or superstitious reasons, as well as through his introduction of alien creatures from other lands. Dr. Ritchie traces in chapters full of original deductions—with all of which some of his readers may not entirely agree—and with a wealth of learning, the complex interaction of these factors in "changing the old Order of Nature." The indirect influence of man on Nature has been "more far-reaching and ultimately more effective in altering the aspect of the countries and of the faunas he has invaded," and from a geographical point of view no influence has been more potent in changing the physical features of Scotland than the removal of the forests intentionally or by the "act of God," the draining of the swamps, and the cultivation of the land. Dr. Ritchie discusses the resultant effects of these factors on the climate, in causing landslides, and the denudation of the hills down to the bare rock, and the greater excavating power of the rains and the torrent-made streams in winter, which carry away the soil to extend seaward the river plains and the boundaries of the shore.

This in brief is the story Dr. Ritchie expounds for his readers in this most interesting volume, handsomely produced and lavishly illustrated by maps, photographs, original drawings, and very apt and charming quotations from almost forgotten Scottish authors of bygone days. His book will be read with pleasure by many who are neither professed geographers nor biologists.

H. O. F.

The Blue Guides. Belgium and the Western Front.— Edited by **F. Muirhead.** London: Macmillan & Co. 1920. Pp. 368 + lxxx. *Sixty Maps and Plans.* 15*s. net.*

This is the third of the new Blue Guides, and maintains the high level of achievement of the earlier volumes. It must have been a difficult task to write a guide to a country undergoing such rapid transitions as are now the fate of Belgium and north-eastern France. Yet even in matters of practical detail the guide is very helpful. The introductory chapters include articles by M. J. Mesnil on Art in Belgium, and by Major-General Sir Frederick Maurice on the British Campaigns in the West. Under every place details are given of its history during the war. Nine sectional maps, contoured and coloured, cover the whole of the British Western Front. They are reproduced from the maps of the Geographical Section General Staff, and are on a half-inch scale. The numerous town plans are very clear, but a few, in this copy at least, have been marred by being folded in a damp state, which has resulted in mutual transference of the black print between opposing faces. This volume, like its predecessors in the series, is a marvel of cheapness.

Il Traforo del Monte Bianco ed i grandi Problemi Nazionali ed Internazionali di Traffico.— **Maggiore Silvio Govi.** *Con* 11 *carte a colori fuori testo e* 15 *illustrazioni.* Milano: Casa Editrice Libraria Luigi Trevisini. [1920.]

The absence of a second Alpine tunnel connecting Italy with France was one of the serious problems of the war, especially after Caporetto. Even with

the improvements carried out on the Mont Cenis line, the means of communication between the two countries proved wholly inadequate. While Lombardy is served by the Simplon and the St. Gothard, and there are four great trunk-lines leading to the Veneto as it is to-day, Piedmont still depends altogether on the Mont Cenis. A new Alpine tunnel is always a political and international question. Thus Bismarck's weight was thrown into the scale in favour of the St. Gothard in opposition to France. But France's turn has come at last, and the new route should obviously link the Val d'Aosta with the valleys of the Arc and the Durance. To effect this connection there are at least three sets of projected tunnels, under the Little St. Bernard, the Great St. Bernard, and Mont Blanc respectively. Apart from technical questions, the Little St. Bernard tunnel would tap the same regions as the Mont Cenis, with which it would therefore compete, and similarly the Great St. Bernard would prove a dangerous rival to the Simplon, and would be vigorously opposed by Switzerland in consequence.

There remains the Mont Blanc tunnel. This would not compete directly with any other. Indeed, it would take the Adriatic traffic from France, leaving western traffic to the Mont Cenis. In fact, it would feed the proposed Italian-Balkan line which will provide a through route between London—Paris—Mont Blanc—Milan—Brindisi—Vallona — Salonika — Constantinople — Baghdad — and India and the East generally. Maggiore Govi considers, of course, that the Channel Tunnel is bound to come. This new Balkan line is, he holds, nearer realization than is generally supposed. Signor Buonomo's plans have been approved and work has actually been begun in the Vojusa valley.

The Mont Blanc tunnel would connect Courmayeur with Chamonix. In fact, De Saussure proposed such a tunnel for foot-passengers and carriages towards the end of the eighteenth century, and the scheme had many supporters as against the Simplon route. Maggiore Govi goes into the technical side of the question in the greatest detail. Quite apart from its main purpose, his valuable book gives a broad comprehensive survey of the whole question of Italian post-war communication problems. L. C.-M.

ASIA

A Lady Doctor in Bakhtiariland.— The late Elizabeth N. MacBean Ross. Edited by **J. N. Macbean Ross.** London: Leonard Parsons. 1921. Pp. viii. and 160. *Portrait and Sketch-map.* *7s. 6d. net.*

This little book of only 160 pages possesses a permanent value. The writer lived as a doctor among the Bakhtiari, winning the confidence of the *Khans* and their wives through her medical skill and knowledge of Persian, with the result that she gives us first-hand information as to the life, the point of view, and the changing conditions among these virile, if unstable, tribesmen. Until the middle of the nineteenth century the entire population was nomadic, grazing their flocks in the plains of Arabistan during the winter and seeking the elevated valleys of the mountains during the summer. About 1850, the *Khans* began to construct castles, and now there is a large settled population, grouped round the residences of the chiefs. From these strongholds, the neighbouring country is dominated and the peasants are ground down cruelly. The term Bakhtiari, according to the author, is generally reserved for the ruling family and their retainers, the peasantry being termed Lur. The bad old order of tyrannical barons is, however, likely to change, for the *Khans*, who posed as champions of the Constitution and of liberty, cannot indefinitely keep their subjects in a state of serfdom. To take another chapter, Dr. Ross writes strongly in favour of

polygamy under the primitive conditions that prevail, and her arguments are weighty and not easily refuted.

The Bakhtiari have sent many of their sons to Europe for education, an experiment that will have a great effect on the tribe—for good or for evil. To meet a typical Bakhtiari Khan, who had been a member of the Officers' Training Corps at school in Essex, and to be accosted in perfect English by him, was an interesting experience that befell me during the World War. Finally, we learn that Bakhtiari dislike poetry, are intensely practical, and study history with passion.

It is a subject for deep regret that Dr. Ross died of typhus while working heroically to save the Serbian nation from that dread scourge, otherwise she would surely have revisited her Bakhtiari friends and studied this powerful tribe, which has played such an important rôle in Persia during the recent struggles against absolutism, with still more fruitful results.

P. M. SYKES.

A Naturalist in Himalaya.— R. W. G. Hingston, M.C., M.B., Captain, Indian Medical Service. London: H. F. & G. Witherby. 1920. *Plates and Text Figures.* 18*s. net.*

'A Naturalist in Himalaya' appeals more directly to the zoological than to the geographical student. Captain Hingston, a most enthusiastic entomologist, possessing keen powers of observation, has given us in this book the fullest and most detailed account of the habits and life-history of numerous species in many groups of insects (especially ants, spiders, bees, and butterflies) that has perhaps yet been published. Eleven out of his fifteen chapters are devoted to insects, one to the mammals, and another to the birds which have come under his observation. The introductory chapter contains a pleasant description of the general features of the scene of the author's investigations, the delightful Himalayan valley of Hazara, a strip of British territory projecting northward into the ranges; while his concluding chapter sketches succinctly the geological history of the region. The rocks of the Hazara Valley are mainly of Tertiary limestone. While the book is not too technical for the general reader, those who are fond of natural history will find its chapters of absorbing interest.

In Unknown China.— S. Pollard. London: Seeley, Service & Co. 1921. Pp. 324. *Illustrations and Maps.* 25*s. net.*

Samuel Pollard.— W. A. Grist. London: Henry Hooks and Cassell & Company, Ltd. [1920.] Pp. 384 + xi. *Illustrations.* 7*s.* 6*d. net.*

"Sam Pollard," as he was affectionately known to his many friends, was a missionary of the United Methodist Church to West China. There he came into touch with the aboriginal tribes of Nosu and Miao who inhabit the mountain regions where meet the three great provinces of Yunnan, Szechuan, Kueichou. Braving perils in the wilds, enduring intolerable hardships, suffering treachery from villainous enemies, robbed, half drowned, cruelly beaten almost to death, he pioneered his winning way into the hearts of Chinese and aborigines alike. Something of his story he told in his little books, 'In Tight Corners in China,' and 'The Story of the Miao.' Later he was induced to write the above book on the Nosu, 'In Unknown China,' but long before it saw the light, the scourge of that region, typhoid fever, destroyed his frail body, and thereby wrung the hearts of many thousands of the aborigines who had learned to love him and to look up to him as a father.

Mr. Grist, who had been his colleague in China, has written this life of a cheery, courageous, saintly soul, and has done his work admirably. It is a

fascinating story, and throws much light on the character and condition of the aboriginal tribes, the lordly Nosu, and the oppressed Miao. Mr. Grist records that the Nosu—generally known as Lolos, a term they abhor—"have a tradition that their ancestors came from Tibet and found Chaotong plain occupied by a dark small-statured race dwelling in caves. Many of the earthen mounds on the plain are thought to be connected with the Yao-ren of a previous age. When uncovered these mounds have been found to contain rough stones and burnt bricks marked with a peculiar pattern. The warlike Nosu are reputed to have driven the Yao-ren into Szechuan, although the Chinese say that the Yao race are the same people as the aborigines in Kwangtung. D'Ollone found traces of these Yao in the north of Yunnan, and maintains that they are the men whom he had observed in Tongking. The bearing of such ethnographical discoveries is obvious. "Certain tribes of French Indo-China are evidently representatives of a race which has occupied enormous tracts of territory, and which, according to some Chinese historians, has played an important part in history, and to-day, in all probability, owing to the alliance of the conquerors with the women of conquered races, they still form the basis of numerous populations." At the beginning of the eighteenth century the Manchus drove the Nosu back into the hills, and then built the city of Chaotong, exacting tribute and submission from the scattered fragments of the Nosu tribe.

Mr. Pollard's own book 'In Unknown China' gives us more information than we have heretofore possessed. The book is a narrative, told in graphic and entertaining style, of his adventurous first journey into Nosu land, but it is enriched throughout by knowledge acquired in later years. Except in a general way the book cannot be said to add greatly to geographical knowledge, but its description of the people, their physical and intellectual character, and their language, manners, and customs, is a contribution of real value to our knowledge of the Nosu, who, with the Miao and other aborigines of West China, number many millions. The Nosu chiefs maintain a feudal system, each chief (t'u mu, "earth eye") having his own territory and defences, his freemen and serfs, who are required to perform services for their holdings and to keep themselves always fit and ready for fighting, which seems to be the normal condition of affairs, as the vendetta is the universal duty of a chief.

Unlike the Chinese the women, both Nosu and Miao, mix on equal terms with the men. Their frank, unsophisticated bearing is a noticeable feature of social life. Religion is in the animistic stage, and the medicine man, or "wizard," is medium, exorcist, and priest. The people live by agriculture in its simplest forms, and by hunting. Their staple food is oatmeal, barley, and maize. A man when travelling takes a bag of oatmeal over his shoulder and eats it raw mixed or washed down with cold water. Some are said to eat two pounds each at a meal, and on this are able to travel three days' journey without another meal. A bag of oatmeal for food and a felt cape for warmth, the cape serving as a coverlet at night, equip a Nosu traveller for any journey, even in the snows of winter, and Nosu land begins its elevation at 6000 feet above the sea.

As to ethnological distinctions amongst the tribes, Mr. Pollard says, "One is bewildered when one first attempts to classify all the tribes of Western China. Long inquiry, however, has led one to simplify them all into two or at most three races. I should divide all these peoples into Nosu, Miao, and Shan. The Shan dwell in the western parts of Yunnan and spread into Burma. The Nosu are all over Yunnan, in the west of Szechuan and in a small part of

Kweichow. The Miao are found all over Kweichow, in some parts of Yunnan and in a few places in Szechuan. Nearly all the tribes one meets with in these three western provinces can be divided into these three classes. One bases this division partly on similarity of customs among the different branches of the same class and partly on evidence furnished by the languages spoken by the various tribes. The Nosu and Miao languages stand in one class and the Shan in another. In nearly all words of the first class the vowel ends the word. . . . These two languages are thus similar to the Japanese, where the same rule prevails. . . . This fact may strengthen the very reasonable idea held by some, that the Japanese race originally came from the east coast of China, where centuries ago the Miao races predominated." He might have added that scattered tribes of them are still found near the coast in Chekiang.

Mr. Pollard gives a number of Nosu words showing the native script and the sounds. The reviewer has repeated these sounds to a Burmese scholar, who was astonished at the close resemblance of many of them to the same words in his own language.

These two books should certainly be read by all who are interested in the aboriginal inhabitants of China, and by those who love adventure.

W. E. S.

AMERICA

Cape Cod and the Old Colony.— Prof. Albert Perry Brigham. New York: G. P. Putnam's Sons. 1920. Pp. xi., 284. *Map and Illustrations.* $3.50.

The sickle-shaped peninsula sticking out on the east coast of the United States, in a latitude about one degree north of that of New York, forms a sufficiently striking feature to rouse some curiosity, but it is of course its historical associations that have begotten so much interest in it on both sides of the Atlantic. The volume now under review, to which, by the way, is prefixed a graceful inscription to the memory of the late Prof. Herbertson, "loyal friend, teacher and inspirer of many, creative thinker in the realm of man's relation to the earth," is one of those brought out to celebrate the tercentenary of the landing of the Pilgrim Fathers on the shores of America. This interest is naturally keener in America than here, which no doubt accounts for the fact that some things about which we on this side would like to have precise information are apparently looked upon by Prof. Brigham as too familiar to need mention. Thus we are told that it was at Provincetown that the passengers of the *Mayflower* landed, but we have to go to other sources to learn that this landing took place on November 11, O.S., 1620; to other sources also for any particulars about the monument which forms the subject of the frontispiece. The volume is a very attractive one both in its text and its numerous illustrations. The text, after giving an account of the settlement of the pilgrims, has two chapters devoted to the physical history of the Cape, one containing theories of its origin, and the other describing changes going on at the present day. The remaining chapters speak mainly of the human history of the Cape, including of course a picture of the life of the people as they now are, when Cape Cod is chiefly known as a restful holiday resort and as one of the chief seats of cranberry-growing in the United States. No one is better fitted than Prof. Brigham to convey to us a sense of the charm of the Cape in the first of these capacities, or to entertain and instruct the reader by suggestions of a wider outlook in setting before us the details of a tiny American county, for Barnstable County which comprises the peninsula is one of the smallest in the United States. He tells us that the first colonists experimented with communistic culture and came close to starvation. "They learned that even

the stern principles that brought them over the sea could not fully control their human qualities, and that some would be lazy if they did not work with the lure of private ownership" (p. 14). In speaking of the cranberry harvest he says that not only is hand picking almost abandoned, but the smaller scoop as well. "The big scoop might seem wasteful if we did not take account of the time and cost of labour. Several barrels of berries may be left on an acre. . . . But the market value of these left-overs would be far exceeded by the cost of rescuing them" (p. 155)—one of many reminders that in the production of raw produce it is not so much the yield per acre that is the important thing as the amount of the return for a given quantity of labour. The larger that return the greater the amount of time left for other work or for wholesome leisure.

G. G. C.

AUSTRALASIA AND PACIFIC ISLANDS

Among the Natives of the Loyalty Group.— Mrs. E. Hadfield. London: Macmillan & Co. 1920. *12s. 6d. net.*

The three larger, and a few smaller, islands of the Loyalty group, lying some 30 miles north-east from New Caledonia, of which geographically and politically, though not anthropologically, they are a dependency, are perhaps less known to the general public, and even to the Hydrographic Department, than any other group of equal importance and comparable history. Discovered either from the *Walpole* in 1800 or from the *Britannia* in 1803, but first seriously examined by Dumont D'Urville in 1827, these islands were annexed in 1853 by France at the same time as the adjacent and very much more important island of New Caledonia. Long before 1853 they had been the resort of British and other sandalwood traders; and in 1841 a Protestant mission station had there been founded, by Mr. Buzacott, of the London Missionary Society, from Raratonga. A French Roman Catholic mission was established soon afterwards, with the usual result of violent rivalry, for ecclesiastical and even civil power, between the two sects. The French, having annexed the islands and having undertaken to establish civil administration in the purely native community, naturally supported the Roman Catholic mission, though after a time the English Protestants were allowed to resume their functions, but as on French territory.

The Loyalty Islands, so near to New Caledonia, which till recently was mainly a convict station, and so far on the direct way thence to the New Hebrides, which offered a convenient refuge to many of the escaped or released French convicts, were visited by few white men, with the exception of the missionaries and a very few French officials, of a kind to facilitate the work of the missionaries in the civilization of the natives.

Mrs. Hadfield, long resident, as the wife of a missionary, in these secluded islands, deals in no way in the book under notice with the history or politics of the group, but has made a very useful addition to their anthropological geography. She makes no claim to being a scientist; and her book cannot be ranked anywhere near the very valuable account of the Loyalty Island folk published by Mr. Sydney Ray in the *Journal of the Anthropological Institute.* She, however, records well and simply the "yarns" which she heard from the lips of some of the older natives, when sitting with them on their mats, round the burning logs which represent domestic hearths in the native huts. She has thus supplied much welcome material from which such men as Mr. Ray may hereafter, even when such traditions have been forgotten in the islands, draw further to elucidate the many problems of geographical as

well as anthropological interest which are connected with the obscure history of the original diffusion of the natives through the islands of the South Seas.

The locality where Mrs. Hadfield has gathered her material is especially important for this purpose, in that the Loyalty Islanders are of Polynesian stock, whereas the New Caledonians are Melanesians, and the Fijians, in the nearest group to the westward, are a curious mixture of folk belonging to both of the stocks just mentioned. For example, the very curious imitation rat which the Loyalty Islanders make of a special cowry-shell with a wrought stone weight of special form, and which they use as a bait for catching cuttlefish (octopods), has been met with, together with some variation of the yarn by which the natives explain it, in Fiji and Tonga, in Samoa, and probably in many other South Sea Islands. Examination of the distribution of the practice should throw at least some small additional ray of light on the large and intricate question on the spread of Polynesians through those seas.

The illustrations to Mrs. Hadfield's book are excellent, and the index is adequate. E. im T.

GENERAL

Fifty Years of Travel by Land, Water, and Air.— F. Hedges Butler. Pp. 422. London: Fisher Unwin. 1920. *Illustrations.* 21*s. net.*

Mr. F. H. Butler is well known in many walks of life, and not least as a pioneer motorist and as founder of the Royal Aero Club. But in this volume he has essayed too big a task, in trying to crowd into a few hundred pages the rambling reminiscences of his varied experiences of land, sea, and air travel in many parts of the world. In parts it is little more than an itinerary with a few stray notes. The fullest chapter, which is on Lapland, is mainly a summary of a volume on that country which the author published a few years ago. The accounts of several visits to Rheims and vicinity during the war give vivid sketches of life behind the battle line. But the only valuable chapters in the book are those on early motoring and ballooning. They have historical interest and might well have been made the basis of a volume. As it stands, the book must have afforded the author much pleasure in writing, and will recall to him and his friends the episodes of happy years, a quality enhanced by the numerous illustrations, most of which emphasize the personal note.

Macmillan's Graphic Geographies. The British Empire.— B. C. Wallis. Pp. 32. *Map and Diagram.* London: Macmillan & Co. [N.D.] 1*s.* 6*d. net.*

A survey of the British Empire in thirty-two pages is an undertaking that a less courageous writer than Mr. Wallis might shirk, especially when the survey is historical as well as geographical. Parts of this pamphlet are instructive, but others necessarily suffer from extreme condensation. In the preliminary survey of the frontiers of various parts of the empire, Malta should hardly be mentioned as "one of the most important ports of call for ocean liners in the world," and St. Helena should not be noted as an Admiralty station. The statement that the Solomon Islands have plantations worked by whites is somewhat ambiguous. On the whole, however, Mr. Wallis has successfully stressed points of importance, and the book is well illustrated by some admirable black-and-white maps as well as several coloured maps. Some of the questions in the test exercises show freshness and ingenuity.

R. B.

The Groundwork of Modern Geography.— **A. Wilmore, D.Sc.** London: G. Bell & Sons. 1920. Pp. xvi. + 396. *Illustrations and Diagrams.* 6*s. net.*

It is rare to find a text-book on this part of the subject so trustworthy and useful as this volume. Dr. Wilmore has successfully escaped most of the pitfalls which await the writer of school books in geography, and moreover has produced a book which is essentially geographical and not a mere collection of scraps of general elementary science. The first and largest section deals with structural geography, the second with climatic geography, and the third with biological geography, including the distribution of plants and animals of economic importance to man. On the whole the allotment of space is sound, since no useful geographical understanding can be gained without a physical basis. The third section is rather brief, but it is questionable how far the wider issues of "human geography" can profitably be discussed at the school stage, at any rate before much regional geography has been studied. Two criticisms are suggested. The distribution of the mosquito and tsetse-fly should be discussed, since probably no forms of wild life have a greater influence on human fortunes. Secondly, the brief, almost laconic, summary of the mental traits of "the four commonly accepted races" might well be omitted; they are misleading generalizations. The illustrations are excellent.

R. B.

THE MONTHLY RECORD

THE SOCIETY

Medals and Awards, 1921.

His Majesty the King has been pleased to approve the award of the Royal Medals as follows: The *Founder's Medal* to Mr. Vilhjalmur Stefansson for his distinguished services to the Dominion of Canada in the exploration of the Arctic Ocean; the *Patron's Medal* to General Bourgeois, Senator for Alsace, Membre de l'Institut, for his long and eminent services to geography and geodesy as Director of the Service géographique de l'Armée, and President of the Conférence Internationale de la Carte du Monde au Millionième.

The Council have made the other awards of the Society as follows: The *Murchison Grant* to Commandant Maury, for his surveys in the Belgian Congo; the *Back Grant* to Miss Marion Newbigin, for her contribution to geography, particularly of the Balkans; the *Cuthbert Peek Grant* to Captain J. B. L. Noel, for his reconnaissance of the eastern approaches to Mount Everest and other geographical work; the *Gill Memorial* to Lieut.-Colonel M. N. MacLeod, R.E., for his contribution to the theory of survey from air photographs.

EUROPE

The Port of Paris.

An illuminating study of the Port of Paris, bringing out within small compass the main facts of its historic development, the system of waterways associated with it, and the character of the traffic maintained, is given by Prof. Demangeon in the *Geographical Review* for November 1920. From the earliest times the fortunes of Paris were intimately bound up with the Seine, whose valley formed one of the highways of commerce from the Mediterranean to North-West Europe. Later, the river contributed materially to the development of Paris, whose "water merchants" were among its richest corporations.

For hundreds of years the Seine supplied Paris with food-supplies and construction materials, and though its *rôle* in this respect became of less importance with the improvement of roads and construction of railways, its port continued to grow with the growth of the city. Three separate sections have in time become merged to form one extensive system. (1) The Seine within the city is in great part lined with wharves and quays, extending on the two banks over more than 14 kilometres, all used more or less for the unloading of building materials, while each group specializes in some particular article. (2) With the growth of Paris away from the river, canals were made which in turn became lined with wharves and also supplied a lateral communication between the Seine above and below the city. (3) The third section developed both above and below the town, chiefly to supply the factories shifted outwards from the centre to the suburbs. As a waterway the Seine is notable among French rivers for its tranquil steady flow, rarely suffering seriously from drought or floods and little impeded by sandbars or gravel banks, so that it is an invaluable artery of commerce for the whole of its region, while the small height of its bordering elevations made it easy to connect it by canals with other basins. Gradually, too, the river itself below the city has been deepened and provided with locks, with a resulting great impetus to traffic, and projects have been set on foot for still further improvements designed to make the port accessible for sea-going vessels (see *Journal*, vol. 37, p. 446). Above the city, the projected canal from the Marne will not only lessen the risk of floods, but will open up a direct route to the sea from Lorraine and the Sarre region, avoiding the tortuous passage through the city. As a port Paris has the advantage of an unusual amount of wharfage, owing to its extensive ramifications, but modern installations for handling the traffic are urgently needed. The character of the trade of Paris is somewhat exceptional. The port is not a centre for foreign trade, nor even a focal point for regional trade, but is essentially a port for the city of Paris alone. A remarkable fact is the disproportion between the outgoing and incoming freight. The Seine brings to the city merchandise for consumption there, but the nature of the shipments has changed completely since the early nineteenth century. Foodstuffs and firewood were for centuries the principal articles of import, whereas now coal and building materials form the bulk of the traffic—more than three-fourths of the whole amount received. The greater part of the outward-bound shipments —85 per cent.—consists of wreckage from the demolition of buildings, framing from construction work, and refuse. Great changes, too, have taken place in the direction of the traffic on the Seine. As long as the river played the chief part in the provisioning of Paris, the port's chief relations were with the upper basin, with some Colonial shipments *viâ* Havre. Now, owing to the large import of coal, the arrivals at Paris are largely from the Lower Seine, Oise, and northern canals. In 1917 over 4,500,000 tons of coal went up to Paris from Rouen, the port where transhipments of cargoes are made, and which may be said to have saved France during the war. In conclusion, Prof. Demangeon asks whether the port must for ever be confined to local uses, or whether it may not in time develop into a great transhipping port.

Ice Movements in Lake Sommen, Sweden.

The effects observable on the shores of lakes due to movements of ice have engaged attention for many years, though no quite satisfactory explanation of the "ramparts" so formed had been supplied until 1884, when Dr. G. K. Gilbert attributed the magnitude of the effect to alternate expansion and con-

traction, the latter causing cracks to develop which, admitting water from below, become filled with new ice on a fall of temperature, with the result that the ice-sheet becomes continually extended shorewards. Modern observations on or discussions of the phenomenon have been referred to from time to time in the *Journal* (vol. 29, p. 577; 32, p. 190; 35, p. 81; 38, p. 79), and the series is now extended by an interesting paper by Dr. Axel Hamberg in the *Bulletin of the Geological Institution of the Univ. of Upsala* (vol. 16, pp. 181–194). After referring to previous discussions, including that of the Swedish geologist Gustafsson in 1902, Dr. Hamberg describes his own observations early in 1919 of ice-movements on Lake Sommen. This had frozen on 28 December 1918, and by March 1 the ice was 28 cm. thick. From February 21 on, the writer took careful observations of the encroachment of the ice on the shore by means of pegs fixed on the latter as well as on the ice. The principal movement took place between February 28 and March 11, by which date the encroachment in a direction at right angles to the shore had reached a total of 34·6 cm., and by March 17 it had increased to 40·7 cm. A lesser displacement parallel to the shore was also observable. Observations taken for a few days both morning and evening showed that the great pushes occurred during the day. The amount of movement is shown to be about that which the theory required on the basis of the observed temperatures and the linear coefficient of expansion of ice. The effects in the direction of piling up the loose material on the shore were less than have been observed elsewhere, perhaps owing to the smaller thickness of the ice. The piling up of the ice itself amounted in places to several metres, whilst in front of rocky shores it was bent upwards even at right angles. Folds were sometimes formed at some distance from the shore, and Dr. Hamberg also observed the formation of transverse ridges (Swedish *råkar*)—narrow zones of crushed and piled-up ice extending across the lake. They show that in a lake of complicated shape the expansion movements originate from several different centres. Such phenomena have not been observed in the extreme north of Sweden, no doubt owing to the northward decrease in the daily amplitude of temperature. Even in southern Sweden this is much less than in the more southern latitudes and more pronounced continental conditions under which the phenomenon has been observed elsewhere.

ASIA

Mount Everest Expedition.

The organization of the expedition is now complete, and all the members proceeding from England have left for India. The leader of the mountain party, Mr. Harold Raeburn, sailed from Birkenhead direct for Calcutta on March 18. Colonel Howard Bury, Chief of the Expedition, left Marseilles for Bombay on April 9, and Mr. G. H. Leigh Mallory, one of the young climbers, sailed from London direct for Calcutta on the preceding day. Mr. A. F. R. Wollaston, surgeon and naturalist, left Marseilles for Bombay on April 16, and by the same boat Mr. G. H. Bullock, who had been selected at the last moment to replace Mr. George Finch, who was unfortunately, owing to ill-health, unable to take part in the expedition this year. These gentlemen, with Dr. Kellas, who is already in India, complete the party of six from this country who will make the reconnaissance, and will, if conditions are favourable and the reconnaissance has clearly revealed the best route, make an attempt this year to reach a considerable height on the mountain. The survey operations will be entirely in the hands of the Survey of India, and we learn from the Surveyor-General that Major Morshead and Captain Wheeler were under

orders to leave Darjeeling about April 1 to carry forward a good triangulation on to the plateau of Tibet with a view to the ultimate determination of the deviations of gravity north of the Himalaya, the question of the first importance to Indian geodesy. At the request of the Government of India an officer of the Indian Geological Survey will also accompany the expedition. The Commander-in-Chief in India, Lord Rawlinson, has responded very kindly to the request that he should assist the expedition by the loan of transport, and a letter has been received recently from the Quartermaster-General detailing orders which have been issued for the selection of trained mules and their accompanying personnel. The transport train was to have assembled at Darjeeling on May 12, and the value of this assistance can hardly be overestimated.

At a recent party at Buckingham Palace the President was summoned both by the King and Queen to give them the latest news of the organization and plans of the expedition, and His Majesty has graciously shown his kind interest in the project by contributing the sum of £100 from the Privy Purse to the expedition's funds. The Chief of the Expedition, Colonel Howard Bury, was received before his departure by H.R.H. the Prince of Wales, Vice-Patron of the Society, who, with the Duke of York, spent an hour in examining the plans of the expedition, and expressed his keen interest and good wishes for its success; an expression that was followed almost immediately by a generous contribution of £50 to the funds of the expedition.

As a result of the appeals made by the President of this Society and the Alpine Club a sum has been collected which is approximately sufficient for the work of the first season, but leaves little reserve. It is, therefore, greatly to be desired that all Fellows of the Society who are jealous for the success of the first important enterprise undertaken since the war, should, if they have not already done so, send subscriptions according to their means to the funds of the expedition.

AFRICA

The Economic Position in Marocco.

A valuable report on the 'Trade, Industry, and Finance of Morocco' was issued last year by the Department of Overseas Trade. The larger part naturally refers to the French Protectorate and affords interesting evidence of the progress made in the direction of economic development in the comparatively short time since the inauguration of the Protectorate, in spite of all drawbacks caused by the war. The most striking progress is perhaps that in the development of the system of roads. When the war broke out, one road only, from Casablanca to Rabat, had been made, but under the energetic impulsion of General Lyautey the making of new roads was prosecuted so vigorously that a network now extends all over the Protectorate in every direction. The only railways have hitherto been 60-centimetre military ones, but work on the normal gauge Tangier-Fez line (international) has been proceeding for some time, and the Protectorate Government has begun work on the Casablanca-Petitjean section of the general railway scheme now being studied; it will eventually be continued to Marakesh. The principal port, Casablanca, suffers from serious congestion, and it is to be regretted that Safi, with the deepest and best anchorage on the coast, capable of handling up to 1400 tons of cargo per diem with no mechanical equipment, has been unaccountably neglected of late. The agricultural resources include the usual cereals and seeds, and experiments in flax and hemp cultivation have given promising results. The mineral resources are still undeveloped, and but little is said about them, beyond the

statement that oil-fields and phosphate beds are likely to be worked before long. A recent rapid advance in industrial development is noted. Large flour-mills have been erected in the main centres, and there are also saw-mills, oil-mills, cement and stone-crushing works, vegetable fibre factories, and various other undertakings. The export trade is now returning to normal conditions, though an embargo is still maintained on the export of cereals, but will be gradually relaxed. The report on the zone of Tangier shows that though the total trade has largely increased in value, the increase in quantity is but small. The United Kingdom has been outstripped by Spain as regards certain articles of import, though she has maintained the lead for others, and in some has gained the lead from France. The port of Tangier is an open roadstead and there is no prospect of early improvement in the facilities for handling cargo. The natural resources of the zone are entirely agricultural, but the production does not meet the requirements. Progress in the Spanish Protectorate has been greatly hindered by the disturbed state of the country. The presence of iron, copper, lead, silver, and other minerals has been demonstrated in many parts of this zone, and the report enters at some length into the prospects of exploitation. At present only four mines are being worked on any scale, all in the neighbourhood of Melilla. The soil is of a quality to promise a good future for farming and stock-breeding, but the indolent character of the natives has kept such activities in a backward state. There are extensive pasture lands and the soil of the "tirs" land is clayey and wonderfully fertile. It is somewhat surprising, however, to read that in these lands the harvest may fail entirely, while the less fertile "hamri" lands and the still poorer and sandy "sahel" always give some return. In spite of the generally abundant rainfall, irrigation could be introduced with advantage, particularly in the basins of the Muluya and the Lukus. A useful map shows roads and railways and the distribution of natural resources.

GENERAL

Climatic Cycles and Biological Evolution.

In a lengthy study, published in the *Geographical Review* for December 1919, Dr. Griffith Taylor reviews multifarious geological, climatological, and palæontological evidence which has led him to the conclusion that the history of the Earth reveals cyclic climatic variations of a twofold character—a major cycle of enormously long period (100,000,000 years) and a minor cycle of relatively very short period (200,000 years). The minor cycles are superimposed upon the major cycles, of which three can be recognized since Proterozoic times, in such a manner that in each major cycle after long ages of fairly uniform climate throughout the world a zonal disposition of climates is established, such as is in evidence at the present time. This zonal arrangement was most prominently developed at the four great ice-epochs in early Cambrian, Devonian, Permian, and late Tertiary or Pleistocene times. In the million years which are thought to have elapsed since the beginning of the Pleistocene, four well-marked "Ice Ages," each about 100,000 years long, separated by a number of milder "Interglacials" about the same length, have left their record, and our present climatological position is designated as the "fourth interglacial of the Pleistocene." It is argued that the more momentous epochs in the evolution of life have coincided with the stimulating zonal climatic periods, the Cambrian marking the dawn of an infinite number of new forms, the Devonian giving birth to the vertebrates, the Permian to the mammals, and the last or Pleistocene "glacial thrust" developing man whose

origin is traced in a series of migrations from Central Asia. In regard to the causation of Ice Ages, Dr. Taylor agrees with Humphreys and Brooks (see *Journal*, vol. 56, p. 146) in showing that extensive mountain-building has synchronized with excessive volcanic activity, though he considers that it is not so much that crustal activity has engendered the northern glaciation as that both were effects of a common cause. For the more recent geological epochs he attempts to estimate the mean temperature of lat. 50° N.—in which the south of present-day England lies—and of lat. 30° N.—the region of ancient civilizations—with suggestions also for the equatorial belt. In the second and most severe Ice-Age of the Pleistocene the temperature of lat. 50° N. was only 35° Fahr. instead of the present 50° Fahr., that of 30° N. was 60° Fahr. in place of the present 76° Fahr., whilst in the warm climate of the Eocene it was as high as 76° Fahr. in 50° N., but not greatly different from the present in the lower latitudes. As an explanation of uniform non-zonal epochs of climate, the writer suggests that the circulation of the atmosphere was then more vigorous than during the zonal periods, with the effect of equalizing the distribution of heat over the globe. This is by no means convincing. Moreover, it is dangerous to form quantitative estimates of climatic change on the basis of biological evidence, for it is surely possible that in the course of ages particular species may vary in their susceptibility to environment. Polar coal and coral no doubt signify milder conditions in the distant past, but the extent of the change can hardly be laid down on such evidence; and it is unsafe to assume, as does Dr. Taylor, that because a certain flora flourished in France during the Pliocene, the country must necessarily have been *five* degrees warmer than now.

The Egerton 1513 Atlas in the British Museum.

In his interesting article on this Atlas in the April number, Mr. Abendanon appears to have overlooked a point, which might prove at once that the Atlas cannot date from before 1541 *at earliest*. This is the naming of the "Grande riuiere des Amazones," which surely shows that the Atlas must have been made after the voyage of Orellana down the great river, completed in 1541, during which it received its present name. In saying that the draughtsman of the Egerton 1513 Atlas may have been the "inventor of the South Continent" it is to be presumed that Mr. Abendanon is thinking only of the French maps of the Desceliers—Desliens type. The Southern Continent had already figured conspicuously in various earlier maps, including the globe of Robert de Bailly of 1530, the heart-shaped maps of Finaeus and Mercator (1531 and 1538), and had appeared in one form or another in Schöner's globes of 1515, 1520, and 1533.

Bamboo for Paper-making.

The search for new sources of supply of various necessary commodities has been speeded up in many directions by the conditions arising from the war, and in no case perhaps are such new sources more needed than for paper-making. Even before the war the threatened diminution of wood-pulp supplies made the question an urgent one, and the possibility of finding substitutes within the British Empire was discussed in 1915 in a paper read by Mr. S. C. Phillips before the Society of Arts (see summary in the *Journal*, vol. 46, p. 160). One of the materials there spoken of as yielding promise of good results was that obtained from bamboo, and the present position in regard to this is now sketched in an instructive article in the *Bulletin of the Imperial*

Institute. The opinion is expressed that the manufacture of paper from bamboo is likely before long to be undertaken on a large scale in several countries. Steps have already been taken to utilize the supply for this purpose from Trinidad, Burma, Madras, and other parts of India, and well-equipped paper factories have already been started in Indo-China. Paper made entirely from bamboo pulp is said to be of high quality, suited for the better grades of printing paper.

OBITUARY

Fred. C. Cornell, O.B.E.

WE very much reget to record the death of Mr. Fred. C. Cornell, whose paper on "The Lower Reaches of the Orange River" was published in the last number of the *Journal*. Those who had the pleasure of hearing his lecture before the Society on 24 January 1921 will long remember his striking personality and excellent style of narrative. He had quite recently made the story of his mineral prospecting in South Africa into a book, 'The Glamour of Prospecting,' which will stand as a very interesting account of that side of his life. But he tells little or nothing of the services he rendered to the Empire through the Boer War, the Rebellion in 1914, and the campaign against the Germans in South-West Africa. His tragic death as a result of a motor accident while on a brief visit to this country is deeply to be regretted, and all who had the pleasure of knowing him will sympathize deeply with the widow and seven children he leaves.

CORRESPONDENCE

Mapping from Air Photographs.

I READ with much interest the article by Lieut.-Colonel S. F. Newcombe in the September number of the *Journal* on mapping from aeroplane photography. The methods he describes are practically the same as those made use of in Mesopotamia from 1917 to 1919 when I was responsible for the mapping of about 2000 square miles of country and some twenty town-plans from aero-photographs. I would point out, however, that the information regarding the Baghdad map derived from Captain Cole is not accurate. A description of the compilation of this map was submitted to the War Office and to you in September 1917 and acknowledged in your letter dated 15 November 1917. We found that for practical purposes of extracting areas, giving the correct areas of buildings, and for other revenue purposes, the adjusted mosaic is not suitable, as it shows only roof areas of buildings, and shadows interfere with the accuracy of detail; it must be turned into a line-plan by a surveyor while actually going over the ground. As regards the mosaic replacing a topographical map, even on a large scale of 1/10,000 our experience proved that even amongst trained map-readers, very few officers could interpret a mosaic correctly. Colonel Newcombe's comparative statements of cost between "air survey by photography" and "survey on ground" are very much in favour of "Survey from the air" as compared with our experience in Mesopotamia and from experiments carried out in India in March 1920.

There is no doubt in my mind that in future the detail of town-plans will

be filled in from aero-photographs instead of from a laborious and slow ground survey, but there will be more ground work than one would expect from reading Colonel Newcombe's article. As an example of comparative cost rates I might mention an area of 9·2 square miles which was mapped from air-photographs and printed in symbols on a scale of 16 inches to 1 mile; the ground was on the outskirts of Baghdad, partly open fields, and partly intricate detail of gardens and buildings. The actual cost from air-photographs was Rs. 4169, and the estimated cost by means of land-survey based on the Survey of India cost rates of cantonment surveys was judged to be Rs. 11,700, both being exclusive of reproduction and printing.

In case it might be of interest I enclose a copy of the report on this map. [Not printed, but placed in Library.]

It must be remembered that our work in Mesopotamia was done with photographs taken under active service conditions; mapping should be greatly simplified by the use of stabilized cameras or other inventions that will ensure the optical axis of the camera remaining truly vertical. I might mention that prints of a large number of town-mosaics enlarged to a scale of 1/880 were supplied to the "Tapu" department in Mesopotamia; these were used merely as key-maps for the registration of property and buildings and no areas or measurements were taken from them; they also proved useful in laying out schemes for water-supply, electric light, and billeting, etc.

In 1919–1920 Colonel F. W. Pirrie, C.M.G., C.I.E., compiled maps from aero-photographs for the Mesopotamian Civil and Military authorities, and has kindly given the following information:—

His experience was that in cultivated areas in Mesopotamia near Baghdad aero-photographs were very useful on the scale 3 inches to 1 mile or larger. The mosaics themselves were of little use as maps unless details were identified, selected, and inked up in conventional map-form on the ground, and irrelevant matter omitted. The heights of walls, banks, and ditches could not be estimated by merely looking at the photographs, and had to be measured, and these relative heights put on the map on the ground. Very close triangulation or traversing would have been necessary unless the orientation and scale of each photograph had been tested by rays and a few actual measurements taken on the ground. The amount of ground survey varied greatly, and depended on whether there was much undulating ground, insufficiently steep to cast a shadow or appear at all on the photographs, or whether the surface vegetation was of a kind that concealed ditches and other relevant ground details. The amount of uncertainty under these heads could never be estimated or got rid of unless qualified ground surveyors were sent over the ground with the separate photographs and combined mosaic.

As regards the most suitable scales for maps compiled from aero-photographs, we found that when using the service cameras and machines the smallest scale suitable for the process is 3 inches to 1 mile; we compiled large areas of inaccessible (enemy) country on the 1 inch scale, but as the R.A.F. did not produce negatives on a smaller scale than $3\frac{1}{2}$ or 4 inches to 1 mile it required a large number of negatives to cover a small area of the map. Perhaps a safe guide for practical work over large areas would be for the negative to be on a slightly larger scale than that of the resultant map; for instance, an 8-inch lens at 10,000 feet gives a negative on the scale of 4·2 inches to 1 mile, which was found quite suitable for the compilation of maps on the 3-inch scale.

I have just read a report by Major C. G. Lewis, R.E., on an experiment in Air-Photo Surveying which was carried out by the Survey of India in March

1920. Many of the conditions were unfavourable, and the R.A.F. used a L.B. type camera with an adjustable cradle. The results seem to confirm the opinions formed in Mesopotamia that air-photography cannot at present compete with ground surveys on a scale smaller than 3 inches to mile.

The experiment in City Surveys was very interesting. The negatives were on the scale of about 1/1800 and the mosaic was compiled on the 1/900 scale; the errors due to distortions were found excessive on this scale. It would appear that under present conditions the largest practical scale is 1/1500 or possibly with negatives free from tilt distortion a scale of 1/1000. This experiment brought to notice many difficulties that must be overcome in the compilation of an accurate large scale town-plan from aero-photographs, and emphasized the fact that skilled surveyors are required for the work, and incidentally entirely refutes Colonel Newcombe's view that a trained surveyor is not necessary for the completion of even a mosaic map.

From a map-maker's point of view it is very necessary to draw attention to the many inaccuracies contained in a photographic negative and to dispel the idea so prevalent that "because it is a photograph it must be correct."

C. P. GUNTER, Bt.-Lieut.-Colonel R.E.

Bangalore, India, 22 November 1920.

MEETINGS: ROYAL GEOGRAPHICAL SOCIETY: SESSION 1920–1921

Eleventh Evening Meeting, 4 April 1921.—The President in the Chair.

ELECTIONS.—The Right Hon. Viscount Buxton, G.C.M.G.; Frank Travers Carlton; Thomas C. Glen-Coats, B.A.; The Rev. Charles Paul Cowland Cooper, M.A.; Robert Gordon Dunthorne, M.A.; Alexander S. Gillespie; Captain Henry Archibald Roger Graham; Andrew Gugushvili; George Frederick Hirst; Captain Ambrose Keevil, O.B.E., M.C.; Lieut.-Colonel M. C. Lake; Robert James Mackintosh; Austin Mardon; B. E. W. Massey; Mrs. Durie Pattullo; Mrs. Beatrice Oliver Smith; George Benson Stewart; Frank Edward Tavener; George Alfred White.

PAPER: The Scenery of Greece. A. W. Gomme.

Twelfth Evening Meeting, 18 April 1921.—The President in the Chair.

ELECTIONS.—Stanwell Alfred Adeney; Vernon G. Cole; Miss Grace Freeth; Captain Ivor Hedley; Lieut. R. V. Hume; Henry Reid Lister; Hugh Penrith Morgan; Ephraim Nicohosoff; Godfrey Charles B. Parish; P. Lee Phillips; Algar Ronald Ward Robertson; Miss Winifred M. Saunders; Charles Robert Webster, O.B.E.

PAPER: South Persia and the Great War. Brigadier-General Sir Percy Sykes.

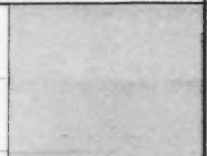
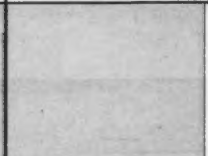
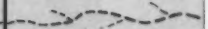
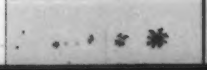
Sixth Afternoon Meeting, 11 April 1921.—The President in the Chair.

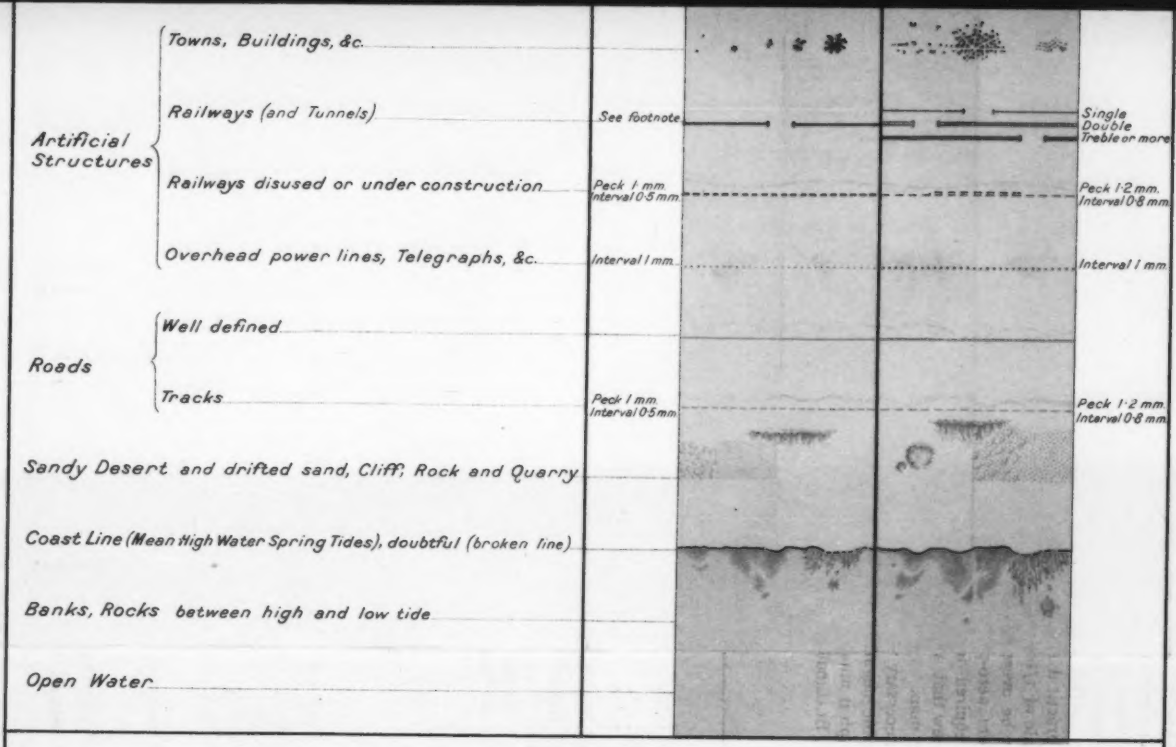
PAPER: The World-Map before and after Magellan's Voyage. Edward Heawood.

INTERNATIONAL AERONAUTICAL MAPS OF THE WORLD.

INTERNATIONAL AERONAUTICAL MAPS OF THE WORLD.

CONVENTIONAL SIGNS FOR THE BASIC MAPS.

	General Map	Local Map	
Ground — Sterile			
Ground — with Vegetation			
Woods, Orchards, Vineyards, &c.			
Water Outline — Rivers, perennial			See footnote
Water Outline — Rivers, non-perennial			
Water Outline — Marsh and areas of Inundation			
Water Outline — Canals			Navigation Drainage Irrigation
Relief — Elevations, perennial Snow, Glacier,			
Relief — Depressions, (Ravine, Wadi, &c.)			
Towns, Buildings, &c.			



NOTES.

Water which appears as more than 0·5 mm. will be shown as 'open' water – dark blue outline and light blue tint. Where of limited extent, the light blue plate may be omitted and graduated lines used thus.–

Where light railways or tramways are shown, the railway symbol is used with the addition of the letter **L** or **T** in black. In closely settled areas tramways will be generally omitted. Where light railways or tramways run along

International

THE GEOGRAPHICAL JO

Water which appears as more than 0·5 mm. will be shown as 'open' water – dark blue outline and light blue tint. Where of limited extent, the light blue plate may be omitted and graduated lines used thus.–

Where an ocean-bed contour is of value to the airman it is shown by a dotted blue line, the depth, in metres indicated by such an isobath being given in black.

The 'lighting' of relief is uniformly from the north-west.

Where light railways or tramways are shown, the letter L or T in symbol is used with the addition of the letter L or T in black. In closely settled areas tramways will be generally omitted. Where light railways or tramways run along roads, except in closely settled areas, the letter L or T, in black, will be given but the railway symbol omitted.

Overhead power lines are distinguished from telegraph lines etc. by addition of the letter P in black.

INTERNATIONAL AERONAUTICAL MA

CONVENTIONAL SIGNS FOR AERIAL INFORMATION

	SYMB
Aerodrome (See notes I&II)	
Emergency Landing Ground (See note I)	
Seaplane Station	
Wireless Telegraph Station, with Radio Goniometer, with Radio Telephony	R R G
Meteorological Station in conjunction with a wireless telegraph station	R
Mooring-mast not at a landing-ground (See note II)	
Name of Aerodrome, Seaplane Station, &c.	FELTH
Aerial Ground Signs showing form of sign (See note VI)	REDHILL
" " " form not shown	
Prohibited Area, small; large	
Aerial Lights	
Marine Lighthouse; 2 or more Lights in close proximity, e.g. harbour lights	
Light Vessel; Light Buoy	
International Boundary	
Line of Equal Magnetic Declination	5° W
Heights, in thousands of metres to one place of decimal, the decimal point indicating the position	5·8 2·0
Wells, permanent; temporary (See note III)	
Aerial Corridor	CORRID

	SYMBOL	NORMAL SIZE IN MILLIMETRES		
		GENERAL MAP	LOCAL MAP	
ISOLATED OR CONSPICUOUS FEATURES (See notes IV & V)				Aerodrome
Fort		1·4	1·5	Aerodrome,
Castle, Mansion		1 X·6	1·1 X·8	
Ruin		1 X·9	1·2 X 1	Aerodrome, S Goniometer; R Station, Aeria
Factory Chimney		·6	·8	
				Aerodrome

L MAPS OF THE WORLD

RMATION (BLACK) PLATES.

Plate I.

SYMBOL	NORMAL SIZE IN MILLIMETRES	
	GENERAL MAP	LOCAL MAP
	True outline and orientation 2	To scale
	True Outline 2; when a circle 1·5 (see note)	To scale When a circle 2·5
	Three circles 4 (broken over land)	Four circles 5 (broken over land)
R G R	Cross 2. Hᵗ of letters ·8	Cross 2. Hᵗ of letters ·8
R H	"	"
	Circle 1·2	Circle 1·8
FELTHAM	Height of letters 1·2	Height of letters 1·5
REDHILL 6 9 1/2	Height of letters 1·1	Height of letters 1·1
	1×2	1×2
	Dots 0·5 apart, lines 1 apart. Width of ruling 2.	Dots 0·5 apart, lines 1 apart. Width of ruling 2.
	Inner Circle 2 Outer Circle 2·4	Inner Circle 3 Outer Circle 3·5
	Inner Circle ·8 Outer Circle 1·7	Inner Circle ·8 Outer Circle 1·7
	Inner Circle ·8 Outer Circle 1·7; ·9	Inner Circle ·8 Outer Circle 1·7; ·9
	Cross 1, interval 1.	Cross 1. interval 1.
5°W	Peck 2, interval 1. Height of letter 1·2	See magnetic symbol on Plate 3
5·8 2·0 ·4	Hᵗ of figures 1·1	Hᵗ of figures 1·1
	Semicircle 1·5	Semicircle 1·5
CORRIDOR	Height of letters ·8	Height of letters 1

SYMBOLS IN COMBINATION

Aerodrome with Wireless Tel. Station — BATH

Aerodrome, Seaplane Sta. & Wireless Tel. Sta. — HULL

Aerodrome, Seaplane Sta., Wireless Tel. Sta., Radio Goniometer, Radio Telephony, Meteorological Station, Aerial Light & Aerial Ground Sign. — R G H T BREST 4F 12

Aerodrome with Aerial Light — WELLS

CHARACTER OF LIGHT

T - Temporary or Seasonal. Lights which are not permanently in operation

A - Alternating. Lights which change colour.

F - Fixed. A continuous steady light.

G - Group. Used in conjunction with "E" or "C" to indicate a group of two or more flashes or eclipses occurring at regular intervals.

E - Flashing. An intermittent light where the total duration of light is less tha that of darkness.

C - Occulting. An intermittent light where the total duration of light is equal to or more than that of darkness.

R - Revolving. A light gradually increasing to full brilliancy and then decrea ing to eclipse.

THE ABBREVIATIONS ARE USED IN THE FOLLOWING ORDER —

I - **Number** of lights if more than one, represented by the single symbol, or more than two if represented by the double symbol. The subsequent descriptions are coupled together severally by the symbol "&" when neccessary for clearness, the higher light or the port light as observed from seaward being described first.

II - **Character**. The order of letters denoting character is that given above; where none is given the light may be assumed to be fixed.

III - **Period** (in seconds) between successive commencements of the same phase and **Number of Flashes or Eclipses**, if more than one with flashing or occulting lights or more than two with group lights. When both numbers are used they are separated by a hyphen. Where it is required to describe the individual phases, the number of flashes or eclipses is replaced by the duration of every phase in seconds, in the correct order, throughout the period and these numbers are separated by commas.

IV - **Nature**. Where the nature is not given it may be assumed to be white. Where the duration of the phases is given the natures are shown in the same order and separated by commas. With alternatin phases is not given, th correct order, separat light or phase varies the exact nature is no

V - **Height** in metres above miles from a point 5 m are given they are sepa is given it indicates he the number when it indi

NOTE 1.
Where the double symbol is coupled together severall tabulated, the order no the lights, thus:- ✱

NOTE 2.
Where lights vary in horizo in being masked to landw shown; otherwise the limi descriptions of such varia

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EXAMPLES :-

★ F 10 = Lighthouse, single light, fixed, white, 10 metres high.

★ Fr/v 13-17 = Lighthouse, single light fixed, sometimes red & sometimes green visibility 17 nautical miles.

☆ E 10 r 7-15 = Light-ship, single light, flashing, one flash every 10 s 7 metres high, visibility 15 nautical miles.

★ TAE 60-2 rw 20-11 = Lighthouse, temporary or seasonal, single lig and flashing, two flashes every minute the first red the 20 metres high, visibility 11 nautical miles.

☆ 2C & E 90-3 & 60 w 10-10 = Light-ship with double light, higher lower light flashing; higher light with 3 eclipses every minu lower light with one flash every minute; both lights white; b a height of 10 metres and visibility of 10 nautical miles.

NS OF LIGHTS

operation.

p of two or
ls.

is less than

t is equal to

hen decreas-

NATURE OF LIGHT

e = electric
w = white
r = red
v = green
b = blue
p = purple or violet
m = masked
i (used after "e", "w", "r", "v", "b" or "p" = a flash of greater intensity.

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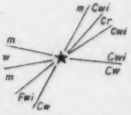
th alternating lights where the duration of the not given, the nature of each flash is given in the der, separated by commas. Where the nature of a ase varies irregularly, e.g. with tidal lights, or where nature is not known, the fact is shown thus: r/v.

etres above sea-level and **Visibility** in nautical a point 5 metres above sea-level. When both numbers hey are separated by a hyphen. When only one number indicates height except when "mil" is written after when it indicates visibility.

ouble symbol is used, instead of the descriptions being ether severally by the symbol "&" they may be the order not having reference to the positions of thus:- ✱ 5F 2Fr. Fv

s vary in horizontal sectors only sked to landward, the fact is not rwise the limitations and s of such variations are shown thus:-



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high.
etimes green, 13 metres high,

every 10 seconds, red,

l, single light, alternating
rst red the second white,

ght, higher light occulting,
every minute and a half,
hts white; both lights with
cal miles.

Factory Chimney	○	·6	·8	
Spire or Steeple, Belfry, Tower, Pagoda, Minaret &c.	+	1	1·2	
Gasometer	⊡	·8	1	
Cemetery	⊞	1X·8	1·2X1	
Quarry, Mine, open to the sky	⚒	1·4	1·6	
Windmill	⊕	·6	·8	
Monument, Pillar, Cairn	⊡	·9	1	
Bridge, Viaduct	⋈	·8	1	
Lock; Dam or Weir, (on river or canal)	› ‹	·8	1·1	
Building	▪	·8X·5	1·1X5	
Prominent Tree or clump of trees; Rock	▽ ▲	·9	1·1	

Station,

Aerodro

I Where
and E
shown
II The fa
by let
of the

III Wells
arid r
IV Consp
isolat
natur
V Consp
may
descr

VI Where
groun
symbo

Station, Aerial Light & Aerial Ground Sign.

Aerodrome with Aerial Light

WELLS

NOTES

I Where the true outline of Landing-grounds (Aerodromes and Emergency Landing-grounds) is not known, it is shown as circular.

II The facilities for aircraft at aerodromes are shown by letters, in sloping Egyptian Capitals, under the name of the aerodrome, as follows:

A = Hangars for aeroplanes
H = Hangars for dirigibles
F = Balloon inflation plant
D = Customs
P = Mooring-mast for dirigibles

III Wells are only shown where of especial importance in arid regions

IV Conspicious features are only shown where they are isolated or dominate over other features of a like nature.

V Conspicious features not included in the above list may be shown as they occur, together with their descriptions thus :– RUINED AQUEDUCT MINE DUMP

VI Where at a landing-ground the form of the aerial ground sign is the name of the station written in full, the symbol for a ground-sign is not employed.

AEG&L 30-5 & 60 W 10-10 = Light-ship with double light, highe
lower light flashing; higher light with 3 eclipses every min
lower light with one flash every minute; both lights white;
a height of 10 metres and visibility of 10 nautical miles.

3 F rrw 10 = Three lights close together, all fixed, light on port s
from seaward) and centre light red and the other light
metres high.

GE 30-1·5, 6, 5, 17·5 w,m,w,m, 12-11 = Light-ship; single light; flashing; period 30 s
as follows: 1½ seconds white, 6 seconds eclipse, 5 seconds white,
eclipse; height 12 metres; visibility 11 nautical miles.

F 3 mil Light buoy with fixed white light, visibility 3 nautical miles.

AFE 60-24, 6, 24, 6 w, wi, w, ri, 33-16 = Light-house; alternating fixed flashing lig
seconds; phase as follows: 24 seconds white, 6 seconds white flas
white, 6 seconds red flash; height of light 33 metres; visibility 16

5F
2Fr = Eight fixed lights: five white, two red, one green.
Fv

NAMES:—

Names of lights are only given when marked so as to be visible
Names where given are printed in upright Egyptian capital
in sloping Egyptian capitals and lower case; the normal hei
1 millimetre for the capitals and ·7 for the lower case, thus

GULL
GE 20-4 w 12-10

every minute and a half,
hts white; both lights with
cal miles.
t on port side (approaching
ther light white, all lights 10

; period 30 seconds; phases
onds white, 17½ seconds

cal miles.
flashing light; period 60
ds white flash, 24 seconds
visibility 16 nautical miles.

be visible from the air.
en capitals, description
normal height being
case, thus:—